NAVSHIPS 91213

RESTRICTED

INSTRUCTION BOOK
for
ECHO BOX
TS-545/UP

JOHNSON SERVICE COMPANY
MILWAUKEE, WISCONSIN

NAVY DEPARTMENT

BUREAU OF SHIPS

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NAVY DEPARTMENT BUREAU OF SHIPS

CONTRACT NObsr-39392 CONTRACT NObsr-42382	Approved by BUSHIPS:	22 June 1949
CONTRACT NObsr-49089 CONTRACT NObsr-52092	CHANGE 2:	16 Feb. 1951
CONTRACT NObsr-43457 CONTRACT NObsr-49254 CONTRACT NObsr-52404	CHANGE 3:	5 Sept. 1951

LIST OF EFFECTIVE PAGES

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RESTRICTED

To: All Activities Concerned with the Installation, Operation and Maintenance of the Subject Equipment.

Subj: Instruction Book for Echo Box TS-545/UP, NAVSHIPS 91213.

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Chief of Bureau

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RECORD OF CORRECTIONS MADE

CHANGE NO.	DATE	SIGNATURE OF OFFICER MAKING CORRECTION

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GUARANTEE

The equipment, including all parts and spare parts, except vacuum tubes, batteries, rubber and material normally consumed in operation, is guaranteed for a period of one year from the date of delivery of the equipment to and acceptance by the Government with the understanding that all such items found to be defective as to material, workmanship or manufacture will be repaired or replaced, f.o.b. any point within the continental limits of the United States designated by the Government, without delay and at no expense to the Government; provided that such guarantee will not obligate the Contractor to make repair or replacement of any such defective items unless the defect appears within the aforementioned period and the Contractor is notified thereof in writing within a reasonable time and the defect is not the result of normal expected shelf life deterioration.

To the extent the equipment, including all parts and spare parts, as defined above, is of the Contractor's design or is of a design selected by the Contractor, it is also guaranteed, subject to the foregoing conditions, against defects in design with the understanding that if ten percent (10%) or more of any such said item, but not less than two of any such item, of the total quantity comprising such item furnished under the contract, are found to be defective as to design, such item will be conclusively presumed to be of defective design and subject to one hundred percent (100%) correction or replacement by a suitably redesigned item.

All such defective items will be subject to ultimate return to the Contractor. In view of the fact that normal activities of the Naval Service may result in the use of equipment in such remote portions of the world or under such conditions as to preclude the return of the defective items for repair or replacement without jeopardizing the integrity of Naval communications, the exigencies of the Service, therefore, may necessitate expeditious repair of such items in order to prevent extended interruption of communications. In such cases the return of the defective items for examination by the Contractor prior to repair or replacement will not be mandatory. The report of a responsible authority, including details of the conditions surrounding the failure, will be acceptable as a basis for affecting expeditious adjustment under the provisions of this contractural guarantee.

The above one year period will not include any portion of time the equipment fails to perform satisfactorily due to any defects, and any items repaired or replaced by the Contractor will be guaranteed anew under this provision.

INSTALLATION RECORD

Contract Number NObsr-39392	Date of Contract 30 June 1947
Contract Number NObsr-42382	Date of Contract 24 June 1948
Contract Number NObsr-49089	Date of Contract 6 April 1950
Contract Number NObsr-52092	Date of Contract 20 Nov. 1950
Contract Number NObsr-43457	Date of Contract 28 June 1949
Contract Number NObsr-49254	Date of Contract 30 June 1950
Contract Number NObsr-52404	Date of Contract 4 June 1951

Serial number of equipment..

Date of acceptance by the Navy..

Date of delivery to contract destination..

Date of completion of installation..

Date placed in service..

Blank spaces on this page shall be filled in at time of installation. Operating personnel shall also mark the "date placed in service" on the date of acceptance plate located below the model nameplate of the equipment, using suitable methods and care to avoid damaging the equipment.

REPORT OF FAILURE

Report of failure of any part of this equipment, during its entire service life, shall be made to the Bureau of Ships in accordance with current regulations using form NAVSHIPS NBS 383 (revised). The report shall cover all details of the failure and give the date of installation of the equipment. For procedure in reporting failures see Chapter 67 of the *Bureau of Ships Manual* or superseding instructions.

ORDERING PARTS

All requests of requisitions for replacement material should include the following data:

1. Standard Navy Stock number or, when ordering from a Marine Corps or Signal Corps Supply Depot, the Signal Corps Stock number.
2. Name and short description of Part.

If the appropriate Stock number is not available the following shall be specified:

1. Equipment Model or type designation, circuit symbol, and item number.
2. Name of Part and complete description.
3. Manufacturer's designation.
4. Contractor's Drawing and Part number.
5. JAN, or Navy Type number.

SAFETY NOTICE

The attention of officers and operating personnel is directed to Chapter 67 of Bureau of Ships Manual or superseding instructions on the subject of Radio-Safety precautions to be observed.

RESUSCITATION

AN APPROVED POSTER ILLUSTRATING THE RULES FOR RESUSCITATION BY THE PRONE PRESSURE METHOD SHALL BE PROMINENTLY DISPLAYED IN EACH RADIO, RADAR OR SONAR ENCLOSURE. POSTERS MAY BE OBTAINED UPON REQUEST TO THE BUREAU OF MEDICINE AND SURGERY.

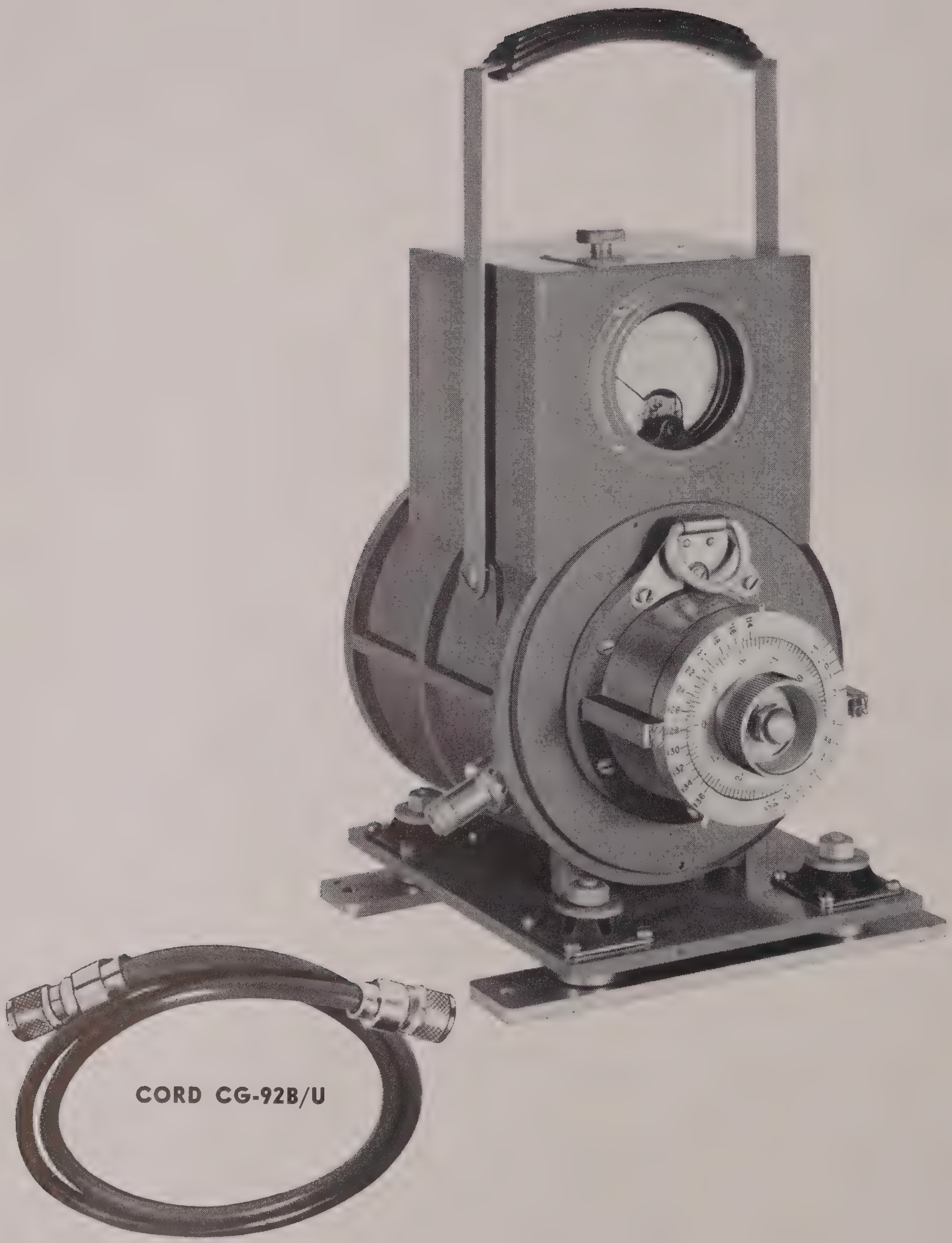


Figure 1-1. Echo Box TS-545/UP

SECTION I
GENERAL DESCRIPTION

1. PURPOSE OF HANDBOOK.

This handbook is intended to furnish instructions for the use and maintenance of Echo Box TS-545/UP.

2. REFERENCE DATA.

a. Nomenclature. — Echo Box TS-545/UP.

b. Contract Numbers and Dates. — Contract NObsr 39392 dated June 30, 1947; NObsr 42382 dated June 24, 1948; NObsr 49089 dated April 6, 1950; NObsr 52092 dated Nov. 20, 1950; NObsr-43457 dated June 28, 1949; NObsr-49254 dated June 30, 1950; NObsr-52404 dated June 4, 1951.

c. Contractor. — Johnson Service Co., Milwaukee 2, Wis.

d. Cognizant Naval Inspector. — Inspector of Naval Material, Milwaukee, Wis.

e. Equipment Shipped. — One package (crate) per shipment. Includes accessories and equipment repair parts.

f. Cubic Contents. — 3.2 cubic feet crated, 1.85 cubic feet uncrated including accessories and equipment repair parts.

g. Total Weight. — 80 pounds crated, 54 pounds uncrated, including accessories and equipment repair parts.

h. Frequency. — 1150 to 1350 mc/sec.

i. Frequency Control. — Hand tuned.

j. Input Impedance. — 50 ohms.

k. Radar Radio frequency power input, averaged over duty cycle, one watt maximum.

3. EQUIPMENT SUPPLIED AND REQUIRED.

a. EQUIPMENT SUPPLIED* — Table 1-1 lists equipment supplied with Echo Box TS-545/UP.

b. EQUIPMENT REQUIRED BUT NOT SUPPLIED — A directional coupler located in the transmission line to the radar antenna is required. The value of the coupling that is desired is treated in Section 2.

c. SHIPPING DATA — Table 2-1 lists shipping data for Echo Box TS-545/UP.

TABLE 1-1. EQUIPMENT SUPPLIED

Quantity per Equipment	Name of Unit	Navy Type Designation	Over-all Dimensions			Volume	Weight
			Height	Width	Depth		
1	Echo Box only	TS-545/UP	11 9/16″	8 1/16″	9 5/8″	.52 cu. ft.	25 1/4 lbs.
1	Separable shock-mounted base only		2 1/4″	8 3/4″	8 1/4″	.094 cu. ft.	4 lbs.
3	Rectifier Crystals**	JAN-IN21B					
2	Instruction Book	NAVSHIPS 91213					
	ACCESSORIES						
1	Cord ‡	CG-92B/U (10 ft.) CG-92B/U (12 ft.)					1 1/2 lbs.
1	Wrench, dial socket						4 oz.
1	Wrench, spanner 1″						1 oz.
1	Strap, carrying						3 oz.

****Shock mounts are supplied with the equipment for use during shipment. Tests have revealed that under certain conditions excessive vibration amplitudes will result when these shock mounts are used in installation. Therefore the shock mounts should be removed whenever this equipment is permanently mounted.***

***** Not supplied on Contract Number NObsr-49089.***

‡ 12 ft. Cord furnished on Contracts NObsr-43457, NObsr-49254 and NObsr-52404.

4. PURPOSE AND PRINCIPLE OF OPERATION.

The TS-545/UP is a portable echo-box test set designed to permit convenient field testing of the performance of radars operating in the frequency range 1150 to 1350 mc/sec. When properly used, this echo box is helpful in recognizing and localizing troubles. The periodic comparison of the "ringing time" observed with that predicted for the particular radar under test will insure that the radar is operating with high efficiency.

Essentially, the test set consists of a hand-tuned resonator (see Figure 1-2) of high Q, excited by means of a loop which is connected by a flexible cable to the r-f test point of the radar. An auxiliary loop connected to a power meter serves as a tuning indication. A transient oscillation is induced in the resonator by the radar pulse. As this transient dies out a signal is fed back to the radar receiver. The time required for this signal to become imperceptible on the radar indicator, expressed in units of radar range, is a relative measure of the performance of the radar transmitter and receiver. Comparison of this value, the "ringing time" with the value predicted according to this manual for the particular radar under test, gives an absolute measure of the radar performance.

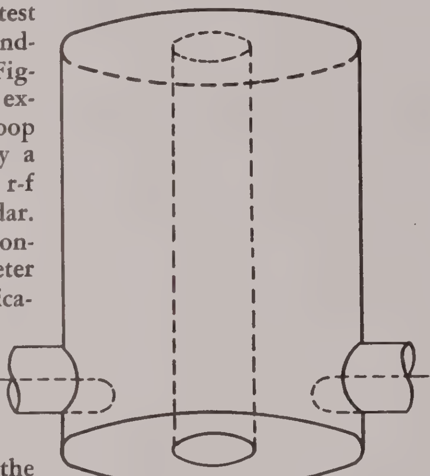


Figure 1-2—Simple Echo Box

5. GENERAL ARRANGEMENT OF ECHO BOX.

a. The TS-545/UP is shown in figures 1-1 and 4-3. The box consists of a cast-bronze cavity cylinder A-104 with a removable bronze end plate A-102. The movable plunger assembly O-106 is actuated by means of the adjusting screw O-102 and the dial N-102. The tuning mechanism is protected by and mounted on the housing A-105. The preloaded ball bearing O-103 reduces the backlash to a negligible amount. Gears are so arranged that the outer dial N-101 travels the amount of one of its divisions while the inner dial makes one revolution (ten major divisions or 100 minor divisions). The gears merely operate the outer dial and have no connection with the driving of the plunger. They cannot cause backlash.

b. On top of the main casting is fastened a mounting bracket A-109 on which is mounted the indicating meter M-101, filter capacitor C-101, and the spare crystal holder A-110. A brass cover A-108 fastened by means of a thumbscrew H-109 covers this assembly. A window A-107 is provided in the front of the cover for viewing the meter scale.

c. An input loop P-102 is inserted in the left side of the main casting. An output loop and crystal holder P-101 containing the crystal Y-101 is inserted into the top of the casting under the meter cover. The input is not adjustable and is installed with a gasket. The output loop may be adjusted by means of the knurled sleeve provided.

d. Two adjusting loops P-103 and P-104, properly set at the factory and requiring no further adjustment, are located on the top of the casting under the meter cover.

e. The whole assembly is fastened to a shock-mounted base. It may be removed from the base and carried by the handle H-101 or the carrying strap H-105 which snaps into the D-rings H-106 and H-153.

f. Figure 1-3 shows the schematic circuit and the wiring diagram, the simplicity of which makes further comment unnecessary. Note that the positive (+) side of the meter is the grounded side.

TABLE 1-2. SHIPPING DATA

Shipping Box No.	Contents		Approx. Overall Dimensions			Volume	Weight
	Name	Designation	Height	Width	Depth		
1	Echo Box	TS-545/UP	17½″	18½″	25″	4.7 cu. ft.	80 lbs.
	Accessory Box		3⅞″	8½″	9⅛″	.175 cu. ft.	8 lbs.
	Equip. Repair Parts		3⅞″	10¾″	12¼″	.3 cu. ft.	10 lbs.
	Instruction Books (2)	NAVSHIPS 91213					

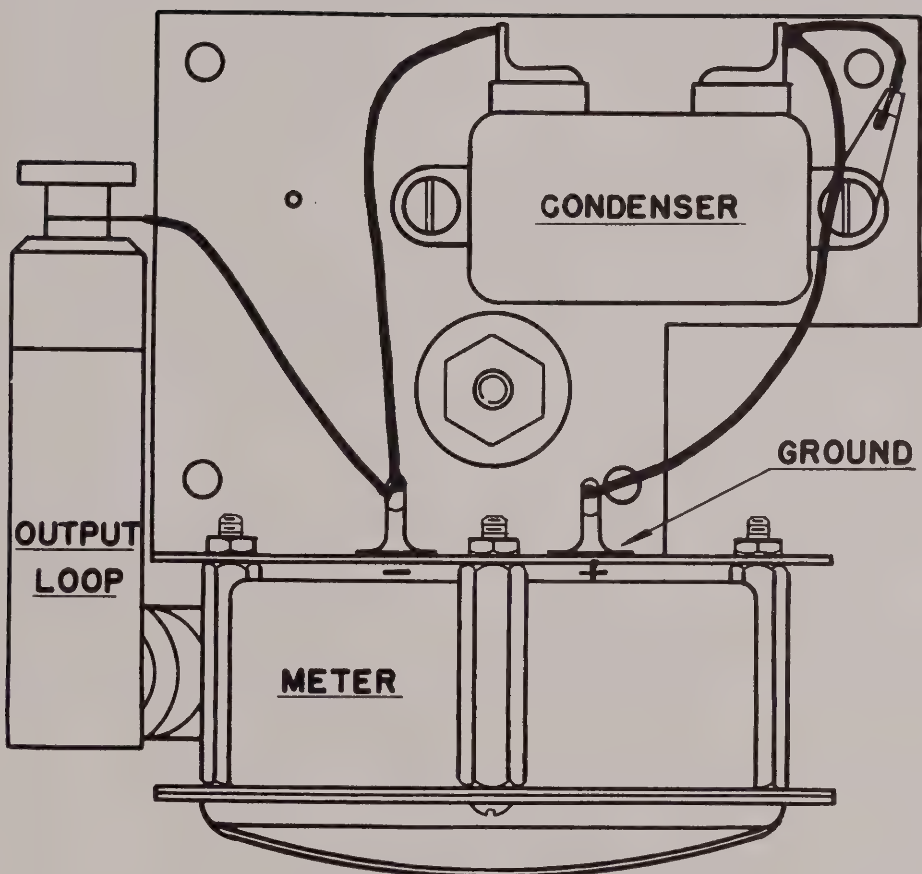


Figure 1-3—Wiring Diagram

Section 2
INSTALLATION, OPERATION, AND ADJUSTMENT

1. INSTALLATION AND ADJUSTMENT.

a. DIRECTIONAL COUPLER. — The directional coupler used with this echo box is permanently mounted as a part of the radar, either as a part of the original equipment or as a field change. The directional coupler required depends on the characteristics of the radar. It must have the same type of transmission line as the radar, and must be suited to the frequency band of the radar. The coupling attenuation of the directional coupler should be such that no more than one watt of average r-f power appears at the input terminals of the echo box. The coupling of a directional coupler is commonly marked on the coupler in decibels. (Hypothetical example: The power of the radar pulse is 500,000 watts, the pulse length is 10 microseconds, or 0.00001 second, and the pulse repetition frequency is 500 cycles per second. The product of these values is the average r-f power of the radar, 2500 watts. This is + 34 decibels relative to one watt; thus the coupling of the directional coupler should be 34 decibels or more. A value of 35 to 40 decibels could be used.) For echo box use, it is desirable that the coupling of the directional coupler be as close as possible in order that the ringing time of the echo box be large. Typical values would be 20 to 35 decibels.

b. MOUNTING THE ECHO BOX. — In case a permanent installation is desired, a location for the echo box should be selected that is convenient to the radar transmitter or indicator, and that, if possible, is close enough to the directional coupler to be within the span of the ten-foot cable furnished. The cable should not be bent on less than a four-inch radius. The shock mount assembly may be fastened to a horizontal shelf or bracket. The echo box is attached to the shock mount assembly by means of four wing nuts, which may be readily removed for portable use of the instrument.

c. CABLE CONNECTION. — The directional coupler and the echo box are connected by the connecting Cord CG-92B/U, or by a special cord made up from Radio Frequency Cable RG-9A/U, and Radio Frequency Plug UG-21B/U, according to figure 4-1. Cables longer than 50 feet should not be used. When the coaxial cable connectors are joined, care must be taken not to turn one connector against the other, as this is very likely to cause the inner conductor fingers to spread. Join the connectors by first inserting them in the proper position, and then turning the outside knurled clamping rings. The fingers of the inner conductor should be periodically inspected and straightened.

d. OUTPUT LOOP ADJUSTMENT. — The amount of r-f power delivered to the echo-box cavity from the directional coupler depends upon the average power of the radar times the pulse length, and is further modified by the length and kind of cable used. Because of this variation, it may be necessary to adjust the coupling between the echo box and the crystal. This is done by loosening the output-loop clamping nut with the spanner and turning the knurled sleeve until a crystal current of about 45 to 55 microamperes is obtained on the crystal meter. The sleeve is then held while the clamping nut is tightened. This adjustment is made only at initial installation; thereafter the loop is left fixed and the meter reading is used as an index of transmitter power.

2. RINGING TIME.

a. INTRODUCTION. — Some of the energy generated by the radar transmitter is picked up by the echo box, via the directional coupler used. This energy excites oscillations in the echo box that persist for some time after the end of the radar pulse, in the same fashion that an echo persists in a room after a loud noise. As this echo dies down, a part of it is fed back into the radar receiving system, again via the directional coupler. This causes a saturated signal to appear on the radar indicator, which is known as ringing. The longer this ringing extends the better the performance of the radar; that is, the more powerful is the transmitter and/or the more sensitive the receiver.

If one knows how long the echo box should ring under the particular conditions of the test (this is called the "expected ringing time"), one may compare the ringing time observed with the expected ringing time to determine whether the radar is performing satisfactorily.

The ringing time to be expected if the radar is in good condition can be set down in advance. It depends upon the characteristics of the particular type of radar being tested, upon the coupling of the directional coupler used, upon the loss of the connecting cord, and upon the temperature of the echo box. In practice, a value called the "uncorrected ringing time" is computed for each type of radar with which a particular TS-545 is to be used. This value includes the effect of all of the above factors except the temperature. In the case of a permanent installation, this value is marked legibly on the echo box by the officer in charge. Instructions for calculating this value appear in Section 3, 1*c*(8).

b. OBTAINING EXPECTED RINGING TIME.

(1) For convenience, the temperature of the echo box should be estimated in degrees Fahrenheit. By reference to figure 2-1, convert this temperature into a percentage factor by which the ringing time is to be corrected. Now increase or decrease the "uncorrected ringing time" by this percentage, as indicated by the plus or minus sign.

(2) Example: Suppose the uncorrected ringing time for a particular installation is 5000 yards. Suppose the temperature of the echo box is estimated to

Figure 2-1. Effect of Echo-Box Temperature on Ringing Time.

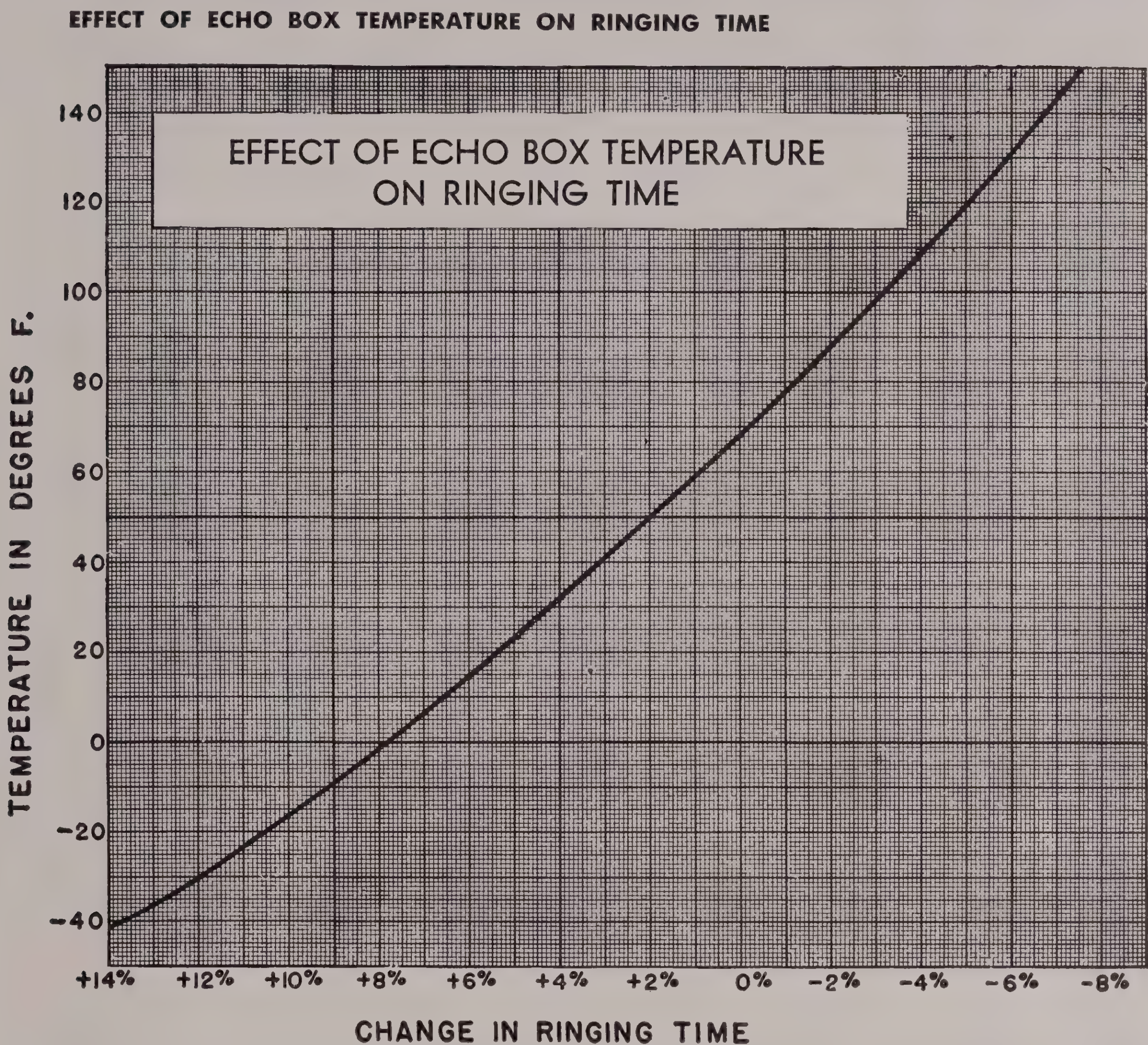


TABLE 2-1 DECIBELS VS RATIOS.

For power measurement the decibel scale is determined by the relation:

$$\text{Power in db relative to } P_1 = 10 \times \log_{10} \frac{P_2}{P_1}$$

DB	P_2/P_1	DB	P_2/P_1	DB	P_2/P_1
— 10	0.10	— 3	0.50	+ 4	2.5
— 9	0.13	— 2	0.63	+ 5	3.2
— 8	0.16	— 1	0.80	+ 6	4.0
— 7	0.20	0	1.0	+ 7	5.0
— 6	0.25	1	1.3	+ 8	6.3
— 5	0.32	+ 2	1.6	+ 9	7.9
— 4	0.40	+ 3	2.0	+ 10	10.0

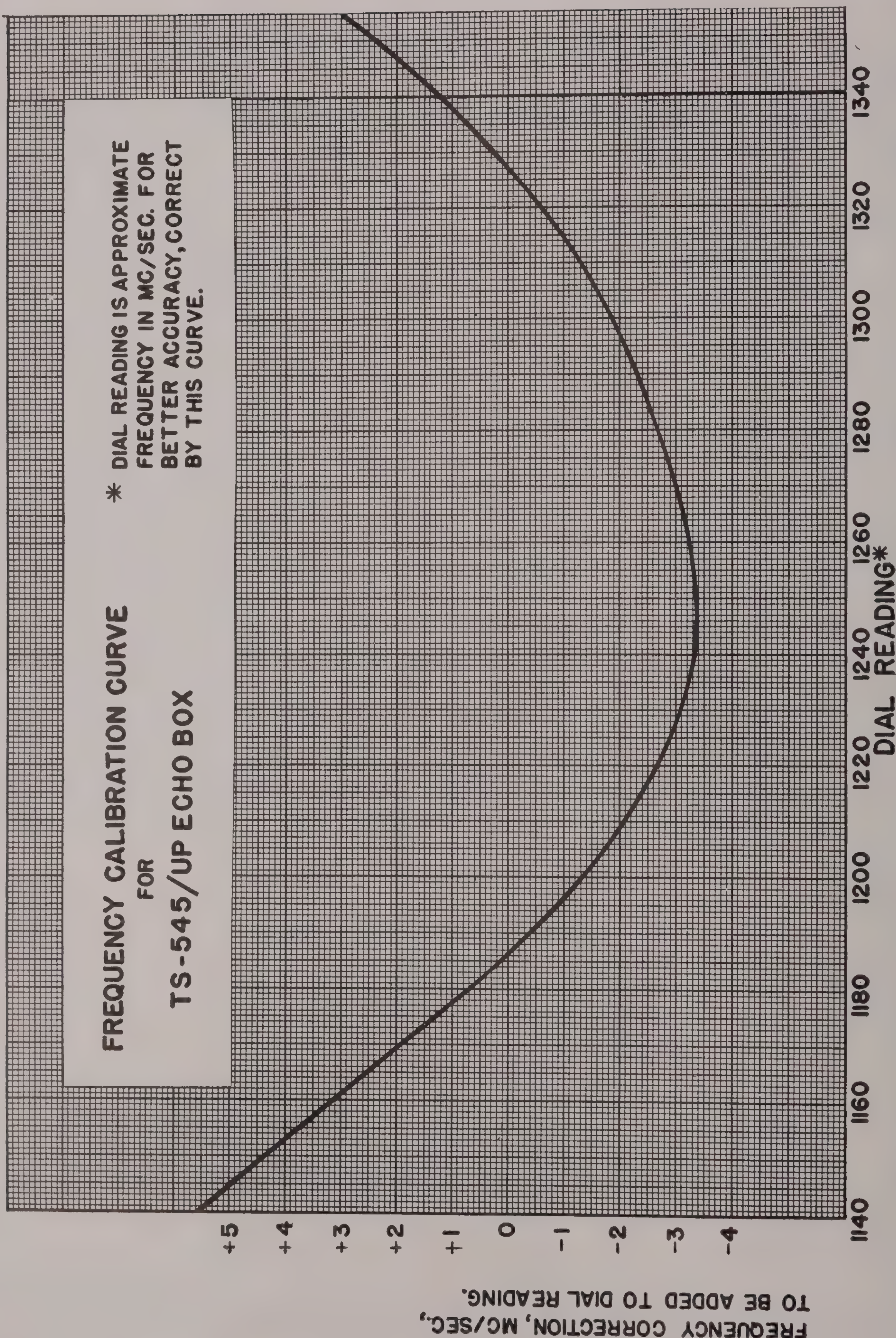


Figure 2-2. Frequency Calibration Curve for Echo Box TS-545/UP

be 40 degrees F. By referring to figure 2-1, it is seen that the change in ringing time is plus three percent. Three percent of 5000 yards is 150 yards, and 150 yards is therefore to be added to 5000 yards, making 5150 yards the expected ringing time. The correction was added because the percentage was plus. Had it been minus three percent, as at 100 degrees F, the correction would have been subtracted from 5000 yards. The value of the uncorrected ringing time must be determined once for each installation; 5000 yards was used above only for the purpose of the example.

(3) If it is not convenient to refer to figure 2-1, the correction may be estimated satisfactorily as being equal to plus one percent for each ten-degree Fahrenheit drop below "room temperature." It is similarly minus one percent for each ten-degree increase above room temperature. "Room temperature" is taken as 70 degrees F.

3. FREQUENCY CALIBRATION.

a. The echo-box dial is read under the transparent index. The outer dial number is read, followed by the inner dial number. Figure 4-3B shows the dial reading 1240.

b. The echo-box dial reading is the resonant frequency of the echo box, accurate to 5 mc/sec. A second scale in red is provided on the dial for the correction of the dial reading to obtain exact frequency. The reading on this second scale is added algebraically to the reading on the first scale to obtain the exact frequency. Figure 2-2 also shows this correction.

4. RINGING TIME MEASUREMENT.

a. PRECAUTIONS IN MEASURING RINGING TIME.

(1) This instruction book makes frequent referency to measurements of ringing time by observation of the indicator of the radar under test. Since ringing-time measurements constitute the most valuable single feature of the echo box, it is essential that they be carried out properly and with due regard for the necessary precautions.

(2) The bearing of the radar antenna should be chosen to produce a clear place on the indicator so that the ringing time may be read without difficulty. Whenever possible, this is most suitably achieved by directing the radar antenna upward so that very few interfering signals will occur and ringing time may be clearly seen on the indicator.

(3) In measuring the ringing time, the tester should make sure that it is the echo-box ringing time that is being received and not some target echo or block of echoes. This can be determined by adjusting the radar gain control and noting whether the ringing time moves back and forth. When this is done, target echoes will change in amplitude, but not in range. The echo-box echo, however, will change in range.

(4) The radar antenna should not be pointed at a mast or other very nearby obstruction as this may cause the transmitter to change frequency.

(5) Turn off any antijamming circuits, also the sensitivity time control and automatic gain control if provided.

(6) Check the adjustment of the ranging circuit.

(7) Always allow enough time for the radar equipment to warm up fully to normal operating temperature.

(8) Tune the echo box to the exact frequency which gives the largest meter deflection. Check over a considerable range to be sure the echo box is not tuned to a side band of the radar.

(9) The radar has a tendency to drift slightly in frequency. When this occurs, the echo box becomes detuned, and accurate ringing-time measurement is difficult. It is therefore necessary, when performing ringing-time measurements for longer than a very few minutes, to retune the echo box from time to time.

(10) Tune the radar local oscillator for exact maximum ringing time, seen on the radar indicator.

(11) In order to obtain accurate results, every ringing-time measurement should be repeated at least four times, and the readings averaged. Care must be taken to make all readings as accurately as possible. If two or more persons use the same echo box, they should practice together until their ringing-time measurements agree.

Practice is very important in reading ringing time. With practice one may detect the weak end of the ringing time which runs out into the grass. The operator who obtains the greatest ringing time reading is usually more nearly correct.

b. MEASURED RINGING TIME ON "A" SCOPE.

(1) The appearance of a good ringing-time pattern on a class A radar indicator is illustrated in figure 2-3. The receiver gain should be set so that the "grass" or noise is one-quarter to one-third the total saturated signal height on the "A" scope. When this is done, a good pattern results, such as that which is shown. In the event that no "grass" can be seen, the gain of the radar i-f is inadequate, and it should be repaired.

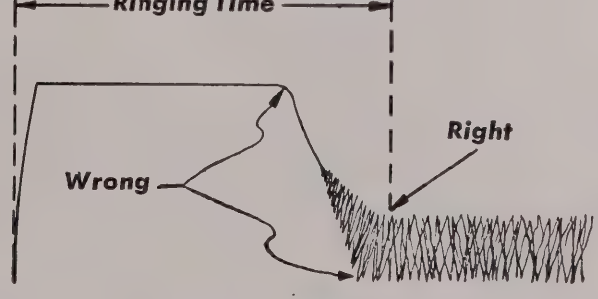


Figure 2-3—Method of Measuring Ringing Time on an "A" Scope

(2) When the ringing time is correctly read, the point at which the pattern disappears into the "grass" caused by background noise is independent of the gain setting within fairly wide limits. It is advisable to adjust the gain until 3/8 inch to 5/8 inch of grass is present. (This is roughly the normal gain setting when searching for small targets).

(3) The exact end of the ringing time occurs at the farthest point to the right at which the TOP of the grass is noticeably above the general level of the rest of the grass. Do NOT judge ringing time by the BOTTOM of the grass, nor by the end of the saturated portion of the ringing time, because these items are influenced by the receiver gain setting, and other factors.

(4) Setting the gain too high or too low may make it difficult or impossible to read the ringing time with any accuracy. (It is essential that grass be present).

(5) The class A indicator measurement of ringing time is usually best performed when the radar antenna is stopped.

c. MEASURING RINGING TIME ON PPI. — If it is not possible to use an A-scope for the measurement of the ringing time, a somewhat less accurate measurement may still be made with the PPI. The same general principles apply. The following standard procedure should be followed:

(1) With the radar antenna in rotation, set the receiver gain at a minimum and adjust the intensity (bias) so that there is a very slight radial trace on the PPI indicator.

(2) Increase receiver gain until the PPI indicator area seems to be just half covered with flecks or "snow."

(3) Good PPI ringing-time patterns, with proper receiver gain adjustment (and with radar antenna rotating) are shown in figure 2-4. The PPI pattern shown is that which results when the echo box is used with a directional coupler, or when the echo box is used with a pickup dipole and both the echo box and dipole rotate with the radar antenna.

(4) If the radar antenna is stopped (for convenience in tuning the radar), the PPI ringing-time pattern will be brighter, but more difficult to read correctly. With the radar antenna stopped, the PPI ringing-time pattern will have the general appearance illustrated in figure 2-5.

(5) It should be remembered that the end of a ringing-time signal is NOT at the place where the bright or saturated part of the signal ends, but where the fainter portion of the signal disappears into the background noise. Therefore, when reading ringing time on a class PPI indicator, be sure to observe to the extreme tip of the pattern, and NOT JUST TO THE END OF THE BRIGHT PORTION of the pattern. Read to the last point at which the "snow" is unusually bright.

5. RINGING TIME, RADAR PERFORMANCE, AND RANGE.

a. RINGING TIME. — When a radar under test shows less than the expected ringing time, it is an indication that the operating or service range of the installation is below par. Ringing time is not directly proportional to radar range. A SMALL LOSS IN RINGING TIME REPRESENTS A GREAT LOSS IN

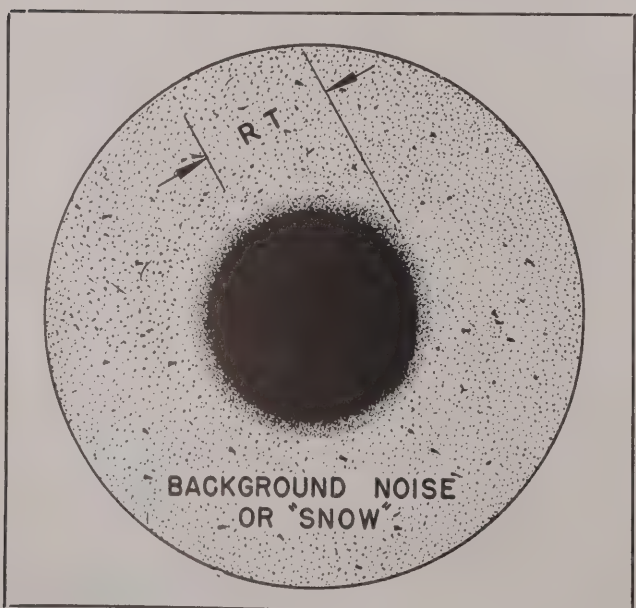


Figure 2-4.
Ringing Time Pattern on PPI Using Directional Coupler.

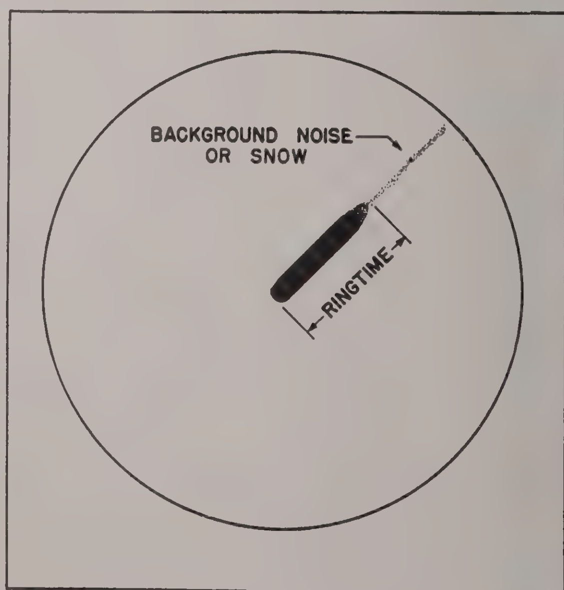


Figure 2-5.
Ringing Time Pattern on PPI With Antenna Stopped.

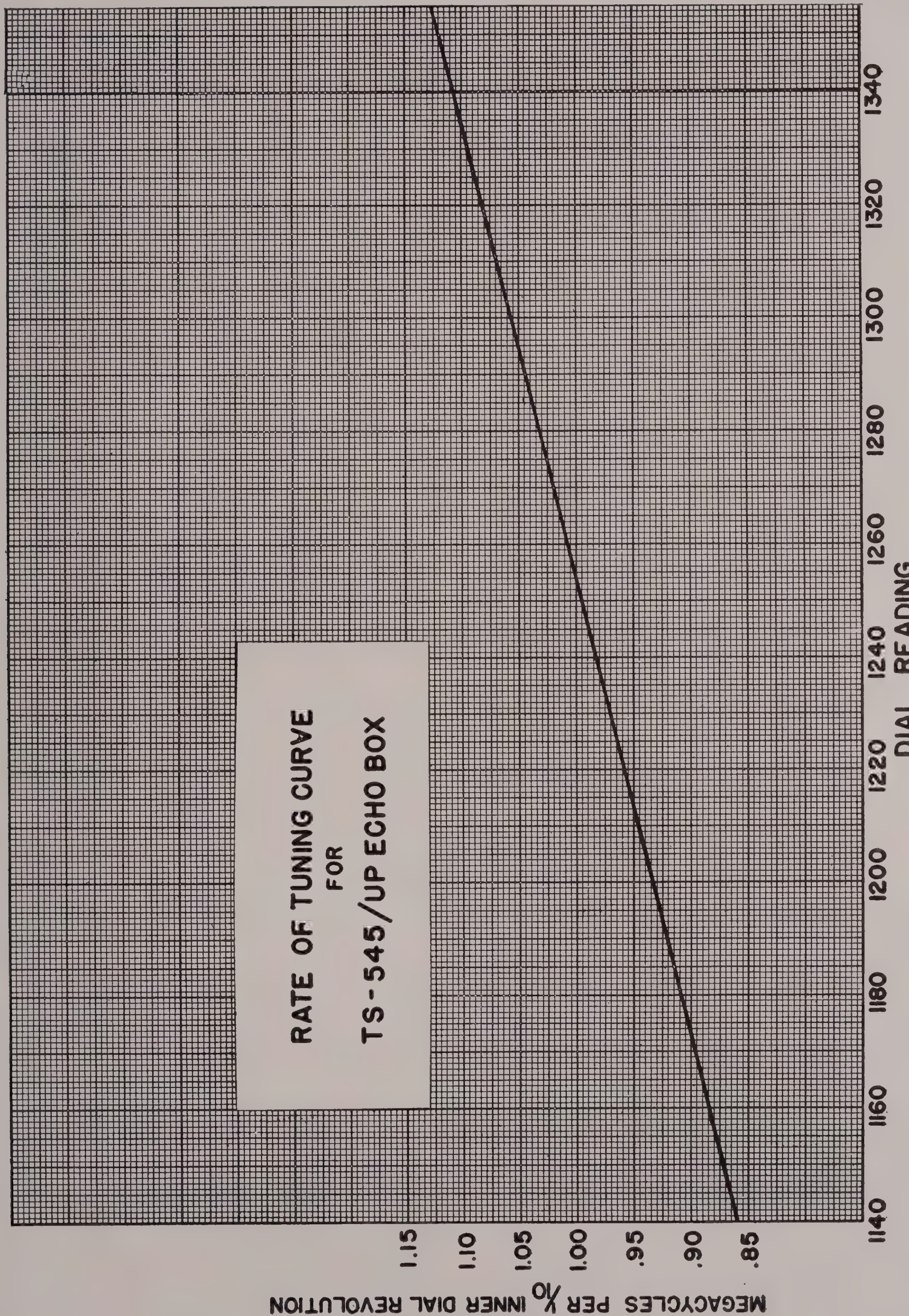


Figure 2-6. Rate of Tuning Curve for Echo Box TS-545/UP

TABLE 2-2.
RG-9A/U CABLE LOSS DATA.

Length of Cable	Decibel Loss
5 ft.	0.4
10 ft.	0.8
20 ft.	1.6
30 ft.	2.4
40 ft.	3.2
50 ft.	4.0

TABLE 2-3.
RINGING TIME, RADAR PERFORMANCE, AND RADAR RANGE.

LOSS IN RINGING TIME IN YARDS	SYSTEM DOWN IN DB	% OF MAX. RANGE AVAILABLE (AIRCRAFT)
75	1½	94%
150	3	84%
250	5	76%
500	10	58%
750	15	42%
1000	20	31%
1250	25	24%
1500	30	18%
1750	35	14%
2000	40	10%
2250	45	8%
2500	50	6%

EFFECTIVE SERVICE RANGE. Security, therefore, demands that ringing time be measured as carefully and as accurately as possible.

b. GUESSING RADAR PERFORMANCE.

(1) Judgment of radar performance "by eye" is extremely inaccurate and unreliable. Checks made with the echo box will often prove that a radar is considerably "down" in efficiency, even when the radar operator thinks his installation has been showing good results. This error in judgment may occur because the operator does not know the true tests of performance. He may, for example, be judging the performance of his set by the strength of a certain well-known or standard signal that he can pick up.

(2) Only too often the signal thus chosen as a measuring stick is one reflected from a large target at a considerable range. The operator is then led to believe that his radar is in good order, since his maximum range seems to be good. However, this common standard of radar performance is insufficient and deceptive. The set may receive good signals from physically large targets, such as are all targets picked up at maximum range, while losing many faint targets (such as target sleeves) that should be picked up at shorter ranges. This occurs because large targets give great echo return and are, therefore, picked up even with relatively poor radar performance unless they are actually beyond the horizon.

(3) EXTREME RANGE PHENOMENA.

(a) An additional factor exists which makes distant targets a very poor choice for radar checks. It is the experience of every radar operator that under certain atmospheric conditions extreme ranges are observed. This occurs because the atmosphere acts as a lens to the rays and bends them around the earth's surface, or because the atmosphere contains a "trapping layer" which prevents the radar beam from spreading in a vertical direction and so concentrates it on the surface of the sea. These effects are due to the change in humidity and temperature as one goes upward in the atmosphere.

(b) Judgment of the performance of a radar "by eye" is very greatly influenced by this phenomenon. In consequence, it appears that distant targets provide the most unreliable sort of index. If performance must be judged by targets rather than test equipment, they should be small targets that are familiar and at short range, giving signals not much larger than the grass.

(4) RESULT OF IMPROVED PERFORMANCE. — After the radar has been in operation for a period of time with reduced performance, the operator becomes accustomed to the condition and ceases to expect better performance. If such a radar is suddenly improved as a result of echo-box measurements, the radar will direct unaccustomed objects, perhaps leading to a "cluttering" of the oscilloscopes. These additional targets are of the magnitude of the objects it is desired to detect, and their presence is a desirable result of the improved performance. If certain tactical purposes require the elimination or reduction in strength of these echoes this can be done with the receiver gain control.

c. MEASURING PERFORMANCE BY ECHO BOX.

(1) RINGING TIME AND RADAR PERFORMANCE.— When accurate ringing-time measurements are carried out with the echo box, the performance of the radar system can be closely checked. The sensitivity of the echo box is used as a mathematical factor in translating changes in ringing time into changes in radar performance. For this type of echo box, the sensitivity is such that each loss of approximately 50 yards in ringing time indicates the radar is "down" one decibel in performance.

(2) PERFORMANCE AND RANGE.

(a) The relation between the level of radar performance and the effective operating range of the radar is illustrated in table 2-3. The table shows changes in radar performance and the corresponding percentage ranges at which certain types of target can just barely be picked up under "normal" weather conditions.

(b) Suppose that a test-set check of a radar gives a ringing time 750 yards short. Since a drop in performance of one decibel represents approximately 50 yards, the radar under test is down fifteen decibels in performance. The table shows that the operating range of the radar is thus down to 42 percent of maximum when searching for aircraft.

(c) It should again be emphasized that these results are typical results, but that "unusual" weather conditions, which are really of frequent occurrence, make range a poor criterion indeed by which to judge radar performance.

6. SPECTRUM ANALYSIS.

a. NATURE OF TRANSMITTER OUTPUT. — Every time a radar transmitter generates an r-f pulse, it produces a certain amount of r-f energy in the form of electromagnetic waves.

(1) Not all of these waves, however, are of the same frequency. Only a small portion of the waves is exactly at the frequency to which the transmitter is tuned. The rest are at slightly higher or at slightly lower frequencies, forming a group of transmitted waves called the side band frequencies. This is the natural and inevitable result of pulse modulation.

(2) In fact, the energy is distributed systematically over a band of frequencies, as in curve A of figure 2-7. This frequency distribution of energy is known as the spectrum. An analysis of its characteristics may readily be carried out with the aid of the echo box.

(3) Properly done and interpreted, spectrum analysis will disclose maladjustments and troubles which might otherwise be difficult to locate. It is desirable,

therefore, that the user of the echo box be able to carry out a spectrum analysis and understand the results.

b. SPECTRUM GRAPHING.

(1) When a spectrum analysis is to be made, the tuning control of the test set is first turned until a maximum output meter deflection is obtained; then the tuning control is turned slowly from a point well below this maximum to a point well above it.

(2) While this is being done, the output-meter readings are noted for various settings of the tuning control. It is good practice to cover the frequency range desired by turning the tuning knob in one direction, *not* by turning it back and forth. This is done to minimize the chance of error due to backlash. A reading should be taken about every 0.01 revolution of the tuning knob (.1 Meg/sec.)

(3) Finally, an accurate graph may be constructed, with the meter readings plotted against the tuning control dial settings. The resulting graph should resemble one of those shown in figure 2-7.

c. SPECTRUM TYPES. — (See figure 2-7.)

(1) A radar transmitter in satisfactory condition should give a spectrum curve similar to curve A or curve B. Good curves are those in which the two halves are symmetrical and in which there are deep well-defined minimum points immediately adjacent to the main peak.

(2) A curve without deep minima, as curve C, indicates that the transmitter output is frequency-modulated during the pulse. This may be caused by a high-voltage pulse (applied to the transmitter tube) of which the sides are not steep enough, or by such a pulse that does not have a flat top. It may also be due to a transmitter tube which is unstable or is operated with improper voltage, current, or r-f load.

(3) When the spectrum is extremely irregular, as in curve D, it is an indication of severe frequency modulation. This will probably cause trouble in the receiver automatic frequency control as well as general loss of signal strength. When the spectrum has two large peaks, quite far apart, it indicates that the transmitter tube is double moding, perhaps because of bad standing waves in the transmission line or a bad transmitter tube. A faulty spectrum can often be improved by adjustment of or by replacement of the transmitter tube. Standing waves may be due to a faulty line connection, a bad antenna rotating joint, mistuned antenna adjustments, obstructions in the line, or damaged waveguide.

d. PULSE DURATION.

(1) In the case of a good or fair spectrum curve with sharply defined minima on both sides of the main peak, the distance between these two minima indicates the duration of the transmitted pulse.

(2) Since the duration of the pulse determines the distribution of power in the side band frequencies, the pulse length may be found from the spectrum graph. The procedure is to determine the distance in megacycles between the minima on either side of the main peak, and then apply this equation: — r-f pulse length in microseconds, measured at the one-half voltage points = 2 ÷ megacycle distance between minima.

(3) From the graph of the spectrum or directly from the dial of the echo box, determine the difference in the dial readings corresponding to the frequencies of the minima immediately adjacent to the main peak of the spectrum. From figure 2-6, determine the rate of tuning of the echo box corresponding to the peak of the spectrum. The product of these is the frequency interval separating the minima. For example, if the dial readings at the two minima are 1333.25 and 1333.85, the difference in dial reading is 0.60, and from figure 2-6 it can be seen that at this frequency the echo box tunes at a rate of 1.10 megacycle per 1/10 inner dial revolution. One-tenth inner dial revolution corresponds to one unit in the dial reading. The product of 0.60 and 1.10 is the exact frequency difference between the minima. This is 0.66 megacycle. The r-f pulse length, measured between the points at which the voltage is one-half the maximum is then 2/.66 or 3.03 microseconds.

(4) Any great change in the spacing in megacycles of the minima of the spectrum from that obtained with a radar of the same type, indicates an improper pulse duration.

(5) The shorter the pulse, the wider the frequency band which the signals occupy. This shows on the graph as a wide span between the minima of the spectrum curve.

(6) An abnormally narrow spectrum shows that the transmitted pulse is too long. Such a pulse could result in a long ringing time and high power reading on the echo-box output meter, thus falsely indicating superior system performance.

e. ROUGH CHECK OF SPECTRUM. — In order to gain experience and skill in spectrum analysis, the tester should plot a few sample curves. For most purposes, however, it is not necessary to plot an accurate spectrum curve. After some experience, the tester will be able to determine the general character of the spectrum by merely observing the meter indication as the echo-box tuning control is slowly adjusted over the frequency range. The spectrum should be classified as good, fair, poor, or bad by comparison wih figure 2-7.

7. POWER OUTPUT.

a. OUTPUT-METER READING.

(1) At the time of installation, the meter reading should have been set between 45 and 55 (by adjusting the output loop) while the echo box was tuned to resonance with the radar transmitter.

(2) The output-meter reading is closely proportional to the average radar power picked up by the echo box, and to the transmitter pulse length, when

the echo box is tuned to the maximum of the spectrum. If the pulse length is long, the spectrum curve is consequently high and narrow, and the meter reading high. Where the pulse length is shorter, the spectrum curve is flatter and the meter reading will be lower.

(3) The power output of a radar is generally good if the transmitter current is normal. Loss in the transmission line may cause loss of power, and this will not be detected at the directional coupler. Because of the value of radar transmitting tubes, careful checking of the echo box and its accessories is indicated before discarding such a tube. See Section 4 for a list of causes which may make the echo-box meter reading low. A considerable reduction in power output should be considered tolerable, perhaps down to one-half power.

(4) NEVER adjust transmitter tuning stubs for maximum power output, as this may make the operation of the transmitter unstable.

8. TEST PROCEDURES.

a. GENERAL PROCEDURE.

(1) A variety of radar equipment checks can be carried out with the aid of this echo box. The exact nature of these tests, as well as the detailed methods of procedure, may vary to some extent between different types and models of radar equipment. The typical procedures outlined below should be a useful basis in establishing test routines to be followed in radar maintenance. Practice and experience may suggest slight variations as the tester gains added familiarity with the echo box.

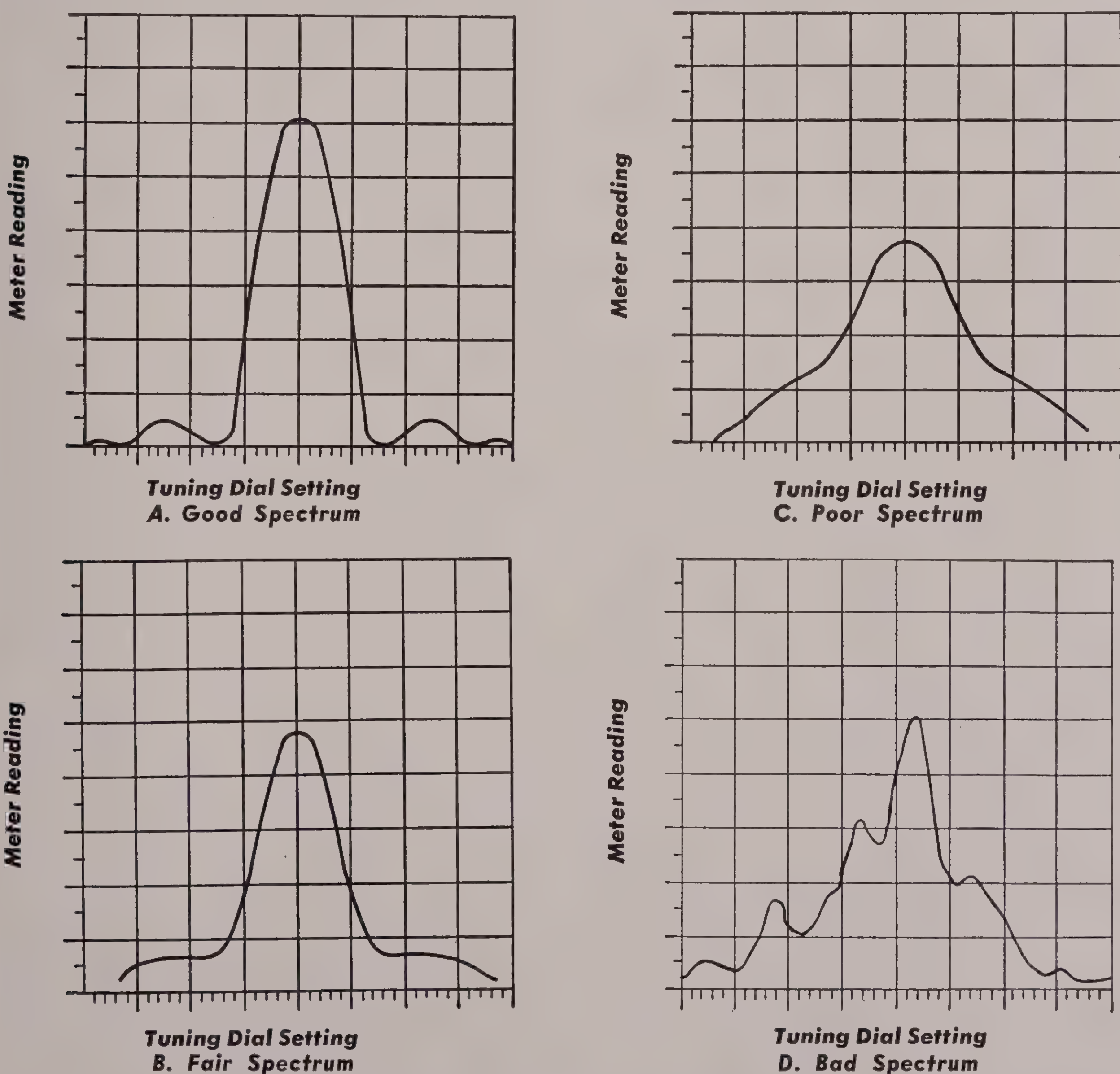


Figure 2-7. Typical Radar Spectra.

(2) In the testing procedure outlined, it is assumed that the echo box is properly installed, and that the expected ringing time and output-meter reading are known for the particular radar under test. It is also assumed that the tester has studied this instruction book and is familiar with the equipment and its use. It is preferable to follow the test procedure step by step. Be sure to RECORD ALL MEASUREMENTS in the radar log. A continuing record of this kind serves as a life history of the installation. It quickly shows up any progressive deterioration in radar performance, and serves as a useful guide in locating maladjustments and defective apparatus.

(3) It is evident that test indications may be used in tuning the radar simply by making the appropriate adjustments and observing the effects upon the test results. The following subparagraphs show when certain adjustments should not be made by echo box indication.

b. PREPARATION FOR TESTING.

(1) As a preliminary step in ALL TESTS, place the radar in operation, and make sure that the directional coupler is properly installed.

(2) Always allow enough time for the radar equipment to WARM UP FULLY to normal operating temperature.

(3) Be sure the echo box is connected to the directional coupler by means of the coaxial cable.

c. TYPICAL TESTS.

(1) OVERALL PERFORMANCE. — Adjust the echo-box tuning knob for a maximum reading of the output meter, indicating that the echo box is tuned to resonance with radar. Then adjust the radar local oscillator frequency for maximum ringing time on the indicator. Measure the ringing time as accurately as possible. (See Section 2-4.) Record the ringing time in the log. Compare this figure with the corresponding value on previous tests, and with the expected ringing-time value for this radar, to determine whether the overall performance of the radar is satisfactory. A loss in ringing time of over 150 yards should be considered a sign of trouble.

LOCATING TROUBLE. — If the output meter and ringing-time measurements observed are both satisfactory (compared to expected values), the radar transmitter and receiver are both functioning well. If the meter reading is satisfactory but the ringing time is low, the radar receiver is the probable source of the trouble. Service the receiver (see Section 3-2), consulting the appropriate radar manual for detailed procedure.

CAUTION

Since the echo box reradiates on an extremely narrow frequency band as compared with the spectrum of transmitter, it is disastrous to attempt any tuning of the receiver i-f stages by means of the echo from the echo box. If such tuning is attempted, the receiver band width may be narrowed and the ringing time will then increase, thus indicating apparently improved radar performance. On the contrary, such i-f tuning will have actually impaired the radar performance.

(2) TRANSMITTER POWER. — The echo-box output-meter reading is closely proportional to the average energy radiated from the radar on a particular frequency. Relative measurement of transmitter power is, therefore, a direct and simple procedure. Tune the echo box to resonance and record the maximum reading on the output meter. This measurement, compared with the corresponding value on previous tests, gives an index of transmitter power. If the meter reading is satisfactory, the radar power output is good. If the meter reading and ringing time are low, the transmitter power output is low, and a spectrum analysis should be made.

CAUTION

R-F adjustments which affect the load impedance, such as transmission line stubs, or line stretchers, or antenna adjustments, should not be adjusted for maximum transmitter power output, as unstable operation may result.

(3) SPECTRUM. — Adjust the echo box to obtain resonance. Then tune the echo box slowly through the frequency range from just below to just above the radar frequency. Record the output-meter reading for each 0.01 revolution of the tuning knob. Plot a spectrum graph and analyze the curve, as discussed in section 2-6.

(4) RADAR-FREQUENCY MEASUREMENTS.

(a) TRANSMITTER FREQUENCY. — Adjust the echo box for maximum deflection of the output meter. Read the tuning knob scale as directed in Section 2-3, and determine the transmitter frequency by referring to the frequency calibration curve of the echo box, figure 2-2.

(b) SETTING LOCAL OSCILLATOR FREQUENCY. — Determine from the radar manual the intermediate frequency of the radar, and if the radar has automatic frequency control, whether the local oscillator is supposed to be set higher or lower in frequency than the transmitter. The local oscillator frequency is the transmitter frequency plus or minus the i-f frequency. Check the transmitter frequency, and add or subtract the i-f frequency, thus obtaining the desired local oscillator frequency. Be careful to perform the correct operation if there is automatic frequency control (afc). Before connecting the echo box to the local oscillator, note the echo-box meter reading at the peak of the radar spectrum, then remove the meter cover and reduce the insertion of the output loop by loosening the locking nut and rotating the knurled adjusting

sleeve. By this means reduce the meter reading to about one-tenth of the previous value. (This is to protect the meter. Following the local oscillator-frequency measurement the echo-box output loop must be carefully set back again to produce the same meter reading on the echo box that prevailed before the test.) Disconnect the echo-box cable from the directional coupler and connect it to the local oscillator, after having disconnected the local oscillator r-f cable. Set the echo-box dial at the desired local oscillator frequency, and tune the local oscillator very slowly until an indication is obtained on the echo-box meter. It is necessary to tune very slowly because of the sharpness of the resonance of the echo box. If it is not convenient to tune the *local oscillator* slowly, the *echo box* may be tuned slowly to discover the frequency of the local oscillator, and the oscillator then adjusted to the desired resonant frequency. Upon restoring the normal echo-box and local oscillator connections, and tuning the echo box to the transmitter, the local oscillator should be sufficiently close to proper tune to permit ringing time to be seen. Final adjustment of the oscillator should be such as to produce maximum ringing time, while the echo box is exactly in tune with the transmitter. (Should maximum echo-box meter reading and maximum echo-box echo not be obtained at the same echo-box dial setting, it is a positive indication that the local oscillator is not in proper tune).

(5) ERRATIC OPERATION. — If the decay trace of the echo box is multiple or erratic while the echo box is tuned as for ringing-time measurement and the radar gain control is reduced slightly to eliminate noise, it is evidence of dissimilar operation of the radar on successive pulses. This may well lead to erratic operation of tracking or spotting circuits and to alignment errors in the radar. It is possible to localize the cause of such operation with an echo box by several tests: First discover whether the appearance of the erratic pattern changes as the echo box is tuned, discounting the inevitable shortening of the pattern as the echo box is detuned. If so, it is probable that the trouble lies in the radar transmitter. Sure confirmation may be obtained by simply connecting the video output of the echo-box crystal to a synchroscope. If the pattern is not a single decay trace the transmitter is at fault, because the receiver is not in the circuit. In the event that the pattern is correct, the transmitter is exonerated and the receiver, particularly the local oscillator, may be suspected. The probable causes of such troubles in the transmitter are: pulling of the oscillator due to fluctuating or erratic r-f load impedance perhaps caused by a bad connection in the r-f line; arcing, or trouble in a lobe-switching device; erratic pulsing of the oscillator or multiple moding in the oscillator. The last may be detected by a spectrum check. It is usual to have a certain amount of jitter in a radar transmitter and this jitter will be most evident when the echo box is slightly detuned. This slight amount of jitter causes the trace to be slightly fuzzy; therefore a slightly fuzzy trace usually suggests that the echo box is a bit out of tune. This normal phenomenon should not be mistaken for trouble. Trouble in the receiver local oscillator may be confirmed by tuning the local oscillator and looking for a changing pattern. The probable causes of erratic operation in the receiver are as follows: modulation of the local oscillator, ripple or other power supply troubles in the receiver, and receiver circuit troubles of an intermittent nature.

(6) T-R BOX RECOVERY. — Stop the radar antenna. Adjust the echo-box tuning control for maximum deflection of the output meter. Adjust the class A indicator of the radar for a good ringing-time pattern, such as curve A in figure 2-8. Slowly and gradually start to reduce the radar receiver gain setting, or better, start to detune the echo box. A pattern will result such as curve B in figure 2-8, having the same relative shape as curve A. Further slight reduction in gain setting will produce another

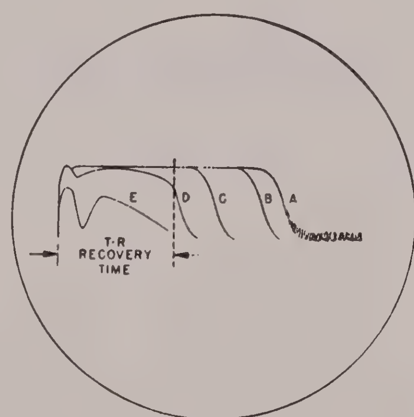


Figure 2-8. Checking T-R Box Recovery.

pattern such as curve C, again similar in shape to curve A. Continue until a change occurs in the slope of the curve, as in curve D. This point of change marks the T-R box recovery time of the radar. For a good radar, the T-R recovery should be at one mile or less.

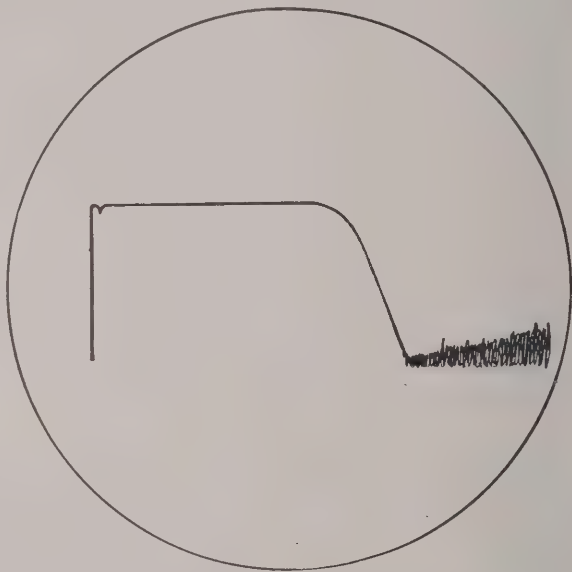
If the gain control is reduced still further, a greatly distorted pattern will appear, such as curve E in figure 2-8. This curve shows that the T-R box has not recovered. If the above procedure does not produce a series of curves (as indicated) giving a T-R recovery point, and if the ringing time is short, then it is probable that the T-R recovery time is much too high (greater than ringing time).

(7) RECEIVER RECOVERY. — Adjust the echo-box tuning control for maximum deflection of the output meter. Stop the radar antenna. Then detune the echo box, and adjust the radar receiver gain control until the indicator shows a pattern similar to the example illustrated at the left of figure 2-9. Now retune

the echo box to resonance and again observe the indicator pattern. If the receiver recovery time is normal, the background noise will reappear immediately after the end of the ringing-time pattern, and this noise will be approximately as strong as the noise previously observed with the echo box detuned. If the receiver recovery is slow, the noise will be weak and will not reappear for some time after the end of the ringing-time pattern (see the right-hand portion of figure 2-9). In extreme cases of receiver nonrecovery, normal background noise may not reappear on the indicator at all. Receiver nonrecovery is usually an i-f tube or a video defect, and one which will make the radar susceptible to enemy jamming.

(8) RAPID TROUBLE-SHOOTING CHART. — When the tester has become familiar with the test procedures and measurements, the echo box may be used for rapid trouble shooting. Radar troubles may be more readily checked with the aid of the cause-and-effect chart, figure 2-10.

ECHO BOX DETUNED



ECHO BOX TUNED

Figure 2-9. Receiver Non-Recovery.

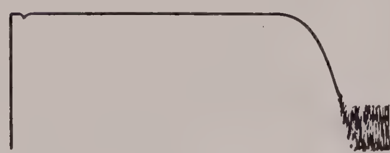
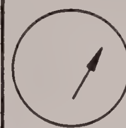
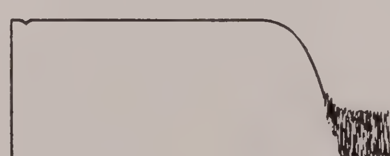
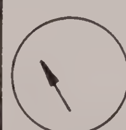
EFFECT	APPEARANCE ON RADAR INDICATOR	APPEARANCE ON TEST SET METER	PROBABLE CAUSE
Ringtime satisfactory, test set output reading satisfactory.			Radar performance satisfactory.
Ringtime low, test set output reading satisfactory.			Receiver trouble: detuned mixer or local oscillator, bad crystal, excessive i-f noise from first pre-amp stage, adjustment of coupling loops or probes in mixer cavity. Detuned T-R box.
Ringtime low, test set output reading very low.			Low power output. Check spectrum.
Ringtime low, test set output reading low.			Trouble probably in transmitter and receiver and/or trouble in transmission line, if dipole is being used.
Ringtime erratic, test set output reading steady.			Test set slightly detuned. Faulty pulsing, double moding transmitter, or local oscillator power supply trouble. Check spectrum.

Figure 2-10—Rapid Trouble Shooting Chart (Page 1 of 2 Pages)

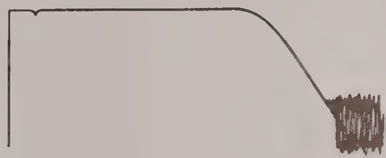
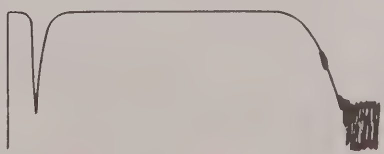
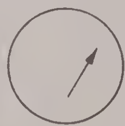
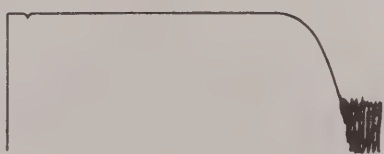
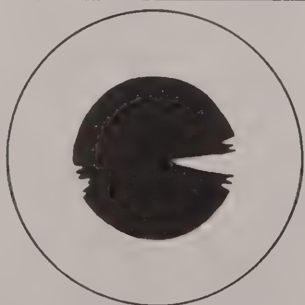
EFFECT	APPEARANCE ON		PROBABLE CAUSE
	RADAR INDICATOR	TEST SET METER	
Ringtime erratic, test set output reading erratic.			Faulty transmission line or poor connections — condition worse when line is rapped.
End of ringtime not steep but slopes gradually; perhaps even excessive ringing. Grass appears coarse. Test set output reading steady and satisfactory.			Oscillating i-f and or narrow band receiver.
Pronounced dip in ringtime at end of pulse.			Bad T-R tube.
Ringtime very slightly low, poor or bad spectrum.			Transmitter trouble.
Blank spaces or rough pattern on PPI ringtime indicator, test set output reading varies as radar antenna is rotated.			Frequency pulling of transmitter due to bad rotating joint or to reflecting object near radar antenna.

Figure 2-10—Rapid Trouble Shooting Chart (Page 2 of 2 Pages)

SECTION 3
THEORY

1. ECHO-BOX FUNCTIONING.

a. ELECTRICAL EQUIVALENT.

(1) The echo box is electrically equivalent to a high-Q (low loss) resonant circuit with lumped constants—that is, with coil, capacitor, and resistor having definite inductance, capacitance, and resistance values. The echo box picks up r-f energy from the radar transmitter pulse and then retransmits some r-f energy back to the radar receiver. When radio-frequency energy is introduced into the echo box, it is stored in the form of radio-frequency electrostatic and electromagnetic fields. These oscillations persist until dissipated by:

(a) Losses within the cavity proper.

(b) Energy withdrawn through the output loop and fed to the output meter circuit.

(c) Energy withdrawn through the two adjusting loops and dissipated.

(d) Energy coupled out by the input loop and fed back to the radar.

b. RESONANCE AND RINGING TIME.

(1) Maximum r-f energy is picked up when a circuit is in resonance with the frequency of an incoming wave. The resonant frequency of the equivalent circuit is determined by the amount of inductance and capacitance, while the resonant frequency of the echo box cavity is determined by its physical dimensions.

(2) The resonant circuit of this echo box is a coaxial transmission line one-half wavelength long, which is shorted at one end by a fixed plate and shorted at the other end by a movable plate. Turning the dial in the clockwise direction shortens the resonator and so raises the resonant frequency.

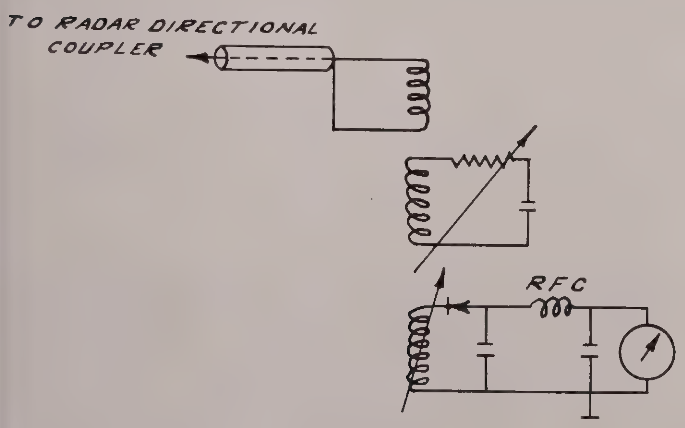


Figure 3-1 — Equivalent Circuit of an Echo-Box

(3) Figure 3-1 shows a circuit which gives the relationship of the echo box to a radar system. The coaxial resonator is coupled to the directional coupler by means of the input loop. This is similar to the way in which the equivalent LC circuit is shown coupled by the antenna link.

(4) Every time the radar transmits a pulse, some of the r-f energy is picked up by the directional coupler and fed into the coaxial resonator through the coaxial cable and the input loop. During the radar pulse, oscillation is induced in the resonator. The oscillations build up for the duration of the pulse. After the pulse ends these oscillations gradually die out, some of the energy being dissipated in the box, some fed to the output meter, and some re-radiated from the echo box.

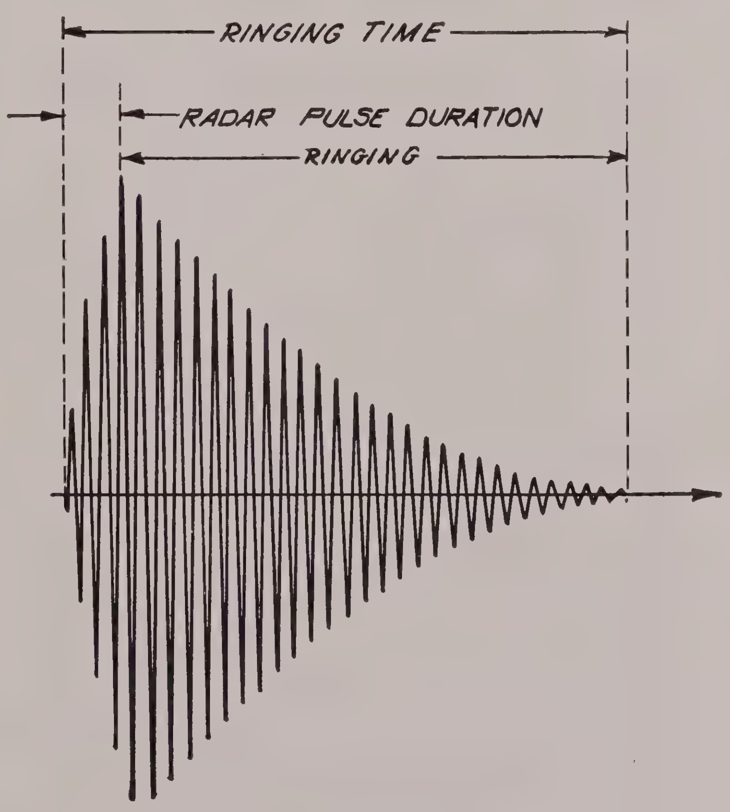


Figure 3-2 — Echo Box Oscillations

(5) Some of this energy is re-radiated through the directional coupler into the radar line and passed on to the receiver, where it causes a pattern on the indicator. During the period when this is happening, the cavity is said to be "ringing."

(6) For purposes of convenience, figure 3-2 has been simplified to show only a few cycles of oscillation during both the radar pulse interval and the ringing. Actually, the former extends to about 750 cycles and the latter extends to 20,000 cycles or more.

(7) During the greater part of the ringing time the signal returned to the radar receiver is extremely strong and the receiver is saturated. This explains the flat top on the pattern exhibited by the receiver class A indicator. Later, as the amplitude of the signal gets lower and the oscillations die down, the indicator trace slopes downward from the flat top and finally disappears into the background noise or "grass" level. This point is, for practical purposes, the end of the ringing time.

c. RINGING TIME PREDICTION AND FACTORS INFLUENCING RINGING. — Outlined below, with explanation, are the factors which determine how long the echo box will ring. The first three factors treated, together constitute the "radar performance," and it will be seen that the other factors fortunately do not affect measurement in an individual installation, but represent differences between radars and between installation of the echo boxes.

(1) TRANSMITTER PEAK POWER — If all other factors are constant, the higher the peak power of the radar transmitter the higher the oscillations in the echo box will build up during the pulse. Since the gradual dying out starts from the level at the end of the pulse, a longer time is taken for the echo-box signal to die down to the receiver noise level. Thus the higher the power of the transmitter the longer the ringing. The ringing time is increased by 50 yards for each increase in transmitter power of one decibel.

(2) RECEIVER SENSITIVITY (NOISE LEVEL). — If all other factors are constant, the lower the receiver-input noise level is made, the longer will be the ringing time, since one is enabled to see the weaker signal which issues from the echo box at a slightly later time. Here again, an increase of 50 yards in ringing time is the result of each improvement of the receiver noise input by one decibel. The receiver-input noise level is the result of two principal factors, the receiver noise figure and the receiver band width. Of these two quantities, the noise figure, which is the general figure of merit of receivers, is the quantity which one is trying to maintain. (The noise figure is the noise per unit band width in a receiver, relative to that which would be present in a theoretically ideal receiver.)

The band width, which does not ordinarily change, also contributes to the noise level. The wider the band width the more noise is permitted to pass. A decrease in the band width, which if large enough might impair the performance of the radar, would actually increase the ringing time. When a receiver, due to interstage feedback, goes into oscillation the band width is greatly reduced, and under such circumstances the ringing is somewhat increased. Oscillation can be recognized by a coarseness of the "grass," by a tendency of the gain to increase abruptly at a particular gain-control setting, and by a slightly less abrupt drop than is usual in the end of the ringing time. Since in radar design the band width is adjusted to suit the pulse length used, there is an interrelation between these two factors both of which separately influence ringing time.

(3) There are several factors which affect both radar performance and ringing time. All these represent losses of either transmitted power or signal power. Losses due to mistuned or defective TR or ATR tubes or other obvious causes comprise this category, and, quite as expected, they cause a loss in ringing time of 50 yards per decibel reduction in radar performance.

(4) Pulse length has considerable effect on ringing time, although it is one of the quantities commonly not variable in a radar. In the case of those radars in which the pulse length may be changed, different ringing times will be obtained on each pulse length. Pulse length effects ringing time in that during a long pulse the echo box "charges up" to a greater extent than during a short pulse. The pulse length may be determined with the echo box as shown in Section 2-6.

(5) The transmitter spectrum influences ringing and also performance in that when bad the transmitter energy may be scattered outside the receiver band width, the signal shape may be impaired, and the AFC may be rendered inoperative. A bad spectrum influences ringing time in that the power applied in the narrow band-pass of the echo box may be reduced due to the greater frequency scattering of the transmitter energy. The spectrum may be determined with the echo box as directed in Section 2-6.

(6) The remaining things which influence the ringing time pertain to the installation of the echo box. The coupling between the directional coupler terminals and the radar is such a factor. The coupling tells what fraction of the transmitter power appears there, and conversely what fraction of the power sent back from the echo box applied to these terminals, reaches the radar line.

The coupling of the coupler reduces the ringing time by twice 50 yards per decibel of coupling; twice because the loss occurs once "going" and once "coming back."

(7) Similarly, the loss in the cable which connects the echo box to the pickup dipole or directional coupler occurs twice, and shortens the ringing by twice 50 yards per decibel loss.

(8) EQUATION FOR UNCORRECTED RINGING TIME. — By means of the following equation, UNCORRECTED RINGING TIME may be computed for a type of radar on which the echo box has not previously been used.

$$R = 6350 + 50 \quad (10 \log \frac{Pt^2}{B} - 2A) + 164t$$

Where.

R = Uncorrected ringing time in yards, for a good radar.

P = Rated peak transmitter power, in kw.

t = Pulse duration, in microseconds. See section 2-6d.

A = The attenuation due to the directional coupler, in decibels, plus the attenuation of the echo box cable. The attenuation of the directional coupler is called the "coupling" and should be found marked on the directional coupler. See Table 2-2 for the attenuation of the echo box cable.

B = Receiver band width (to points of ½-power response) in megacycles.

This equation summarizes the preceding paragraphs (1) through (7).

(9) SAMPLE CALCULATION. — Using the above equation, we can determine the uncorrected ringing time for a radar whose design characteristics are known. Suppose the peak transmitter power of this radar is 200 kw, the pulse length is 1 microsecond and the receiver band width is 2 mc. The coupling of the directional coupler is 27 decibels.

Evaluating the equation for R we get:

$$R = 6350 + 50 \left(10 \log \frac{Pt^2}{B} - 2A\right) + 164t$$

$$R = 6350 + 50 \left(10 \log \frac{200 \times 1^2}{2} - 2 \times 27\right) + 164 \times 1$$

$$R = 6350 + 50 (10 \log 100 - 2 \times 27) + 164$$

$$R = 6350 + (20 - 54) + 164$$

$$R = 6350 + 50 (-34) + 164$$

$$R = 6350 - 1700 + 164$$

$$R = 4814 \text{ yards}$$

The uncorrected ringing time for this radar has thus been found to be 4814 yards. In round figures this may be called 4800 yards.

NOTE

The uncorrected ringing-time value obtained in the calculation above is not corrected for echo box temperature, consequently corrections must be made to obtain the expected ringing time for the radar, according to section 2-2.

d. OUTPUT-METER CIRCUIT.

(1) A portion of the energy stored in the echobox resonant cavity is withdrawn by the output loop and transmitted to the rectifier crystal, filter condenser, and output microammeter circuit. The characteristics of the output-meter circuit and its coupling to the ringing cavity are such that the meter deflection is approximately proportional to the energy introduced into the cavity from the radar transmitter at the frequency to which the test is tuned.

(2) The filter condenser causes the meter circuit to have a low impedance to the voltage pulse from the crystal.

(3) The meter reading may be expected to be proportional to the pulse length as well as to the average power of the radar, since long pulses produce narrow and proportionately high spectra, and vice-versa.

e. ADJUSTING LOOPS. — The two adjusting loops, P-103 and P-104, figure 4-3, are set at the factory to make the ringing time of all echo boxes the same, and to cause the ringing time to be constant over the frequency band. P-103 is set to make the ringing time independent of frequency, and P-104 is set to make the ringing time standard. These adjustments are sealed, and cannot be adjusted in the field. If they are disturbed it will alter the ringing ability of the echo box and this will invalidate further measurements.

2. RADAR FUNCTIONING.

a. RADAR PERFORMANCE.

(1) The efficiency of a radar in seeing targets under given external conditions depends on the radar performance. Radar performance consists of two main factors:

(a) The power in the pulse sent out from the antenna, measured when the pulse has correct frequency distribution.

(b) The receiver sensitivity, measured by the power of the smallest signal that will produce a pip on the indicator that is just discernible above the noise level.

(c) The above may be formulated as:

$$\text{Radar Performance} = \frac{\text{Peak Power Output}}{\text{Minimum Discernible Signal}}$$

(d) Radar performance is therefore a power ratio, and is consequently measured in decibels according to the following equation: Power P_2 in db relative to Power $P_1 = 10 \times \log_{10} \frac{P_2}{P_1}$ where P_2 and P_1 are the powers being compared. (The decibel affords a convenient means of indicating performance in simple figures, avoiding the difficulty of expressing large numbers). For a radar in good condition the performance has a magnitude of 170 db or more.

(e) A drop of 3 db in performance (often stated as "3 db down") equals a decrease to ½ in the power ratio - - that is, a ½ drop in output or a doubling of the receiver noise. A gain of 3 db in performance equals a rise to twice the output or a halving of the receiver noise. Similarly a drop of 10 db = a decrease to 1/10 in power ratio, a drop of 20 db = a decrease to 1/100 in power ratio, a drop of 30 db = a decrease to 1/1000 in power ratio. Decibels are added

where ratios would be multiplied, hence, a drop in power ratio to 1/20 (equivalent to 1/10 times ½) would equal a drop of ten decibels plus three decibels, or a drop of 13 decibels.

(2) The foregoing paragraphs do not mean that all radars with equal performance can see the same targets equally well. Radars are not always designed for the same purposes nor are they similarly installed; in addition, the weather has a large effect upon the ability of a radar to see targets. Radar performance, instead, is a measure of that part of the ability to see targets which is under the control of the maintenance man.

b. COMPONENTS INFLUENCING PERFORMANCE. — In the radar, a radio-frequency pulse is produced in the transmitter tube, which is some form of high-frequency oscillator. For good performance, the pulse must have the proper frequency spectrum and must be of the desired power. This pulse must be sent to the antenna through the r-f transmission line with as little loss as possible, and then must be radiated from the antenna. If a portion of the pulse power sent out from the antenna is reflected back to the antenna as a signal, it must be conducted without appreciable loss, through the transmission line, through the T-R tube, and to the mixer. In the mixer, the r-f signal is mixed with the cw output of a local oscillator to produce a beat frequency, or intermediate frequency, at which frequency the signal is amplified sufficiently to produce a voltage pulse that can be used for indication. Noise generated in the receiving system is amplified along with the signal itself. By careful design and maintenance the receiver may be made to have a good sensitivity, which means a low level of internally generated noise. The receiver MUST have enough gain so that noise may be sent on the indicator together with the signal, otherwise the maximum sensitivity of the receiver is not utilized, and therefore the performance of the set is lowered.

(1) Performance is influenced by the transmitter, because it determines the power and frequency characteristics of the pulse.

(2) It is influenced by the condition and tuning of the transmission line adjustments, which must be properly tuned or attenuation through them may be great.

(3) Performance is also influenced by the tuning of the T-R and the condition of the T-R tube.

(4) In the preamplifier, mixer, and receiver, performance is influenced by the frequency and power of the local oscillator input to the mixer, by the effectiveness of the r-f to i-f converter, and by the noise generated in the first r-f tube and first i-f tube.

(5) Beyond the first i-f stage, performance is not greatly altered by the characteristics of the receiver. The receiver overall band width may vary within wide limits and remain satisfactory. Gain is not important, except that it must be sufficient to allow noise to be seen on the indicator.

(6) Other components of the radar system (modulator, synchronizer, etc.) must, of course, be functioning properly, but they have little part in determining overall performance.

c. RELATIVE IMPORTANCE OF COMPONENTS. — The relative influence upon performance of the components mentioned above must be understood in testing a radar set.

(1) Ruinous losses are most likely to occur in the components that deal with the received signal from the time it is picked up by the antenna until it passes the first i-f stage.

(a) Small troubles, bad connections, and lack of adjustment, unimportant though they may seem, may cause the complete loss of a signal as weak as that picked up from a small target. The receiving part of the radar is by far the most likely place for the occurrence of losses that affect performance.

(b) Noise generated in the preamplifier and mixer cannot be reduced below some certain minimum. If a signal has dissipated too much of its energy before reaching the receiver, no amount of amplification will enable it to be seen above this noise on the indicator, since the noise is amplified with the signal.

(c) In the receiving system there are many opportunities for half or more of the signal power to be lost, and pyramiding of these losses may make the performance extremely poor.

(2) The transmitting system is not as likely to be the cause of impaired performance.

(a) If more than half the output power is lost, the trouble will usually be indicated by improper transmitter current, a spectrum of low amplitude, standing waves in the r-f line, or arcing in the line.

(b) The output may go down to one-half (3 decibels down in radar performance) of the optimum without seriously affecting performance provided all other components function well.

(3) Serious performance losses do not commonly arise in the intermediate-frequency stages that follow the first i-f tube, or in the video sections of the receiver.

3. COUPLING RADAR AND ECHO BOX.

a. There are several devices for coupling a sample of power out of a radar for test purposes. Their object is to make a portion of the r-f power from the radar available for power measurement and provide a convenient method of feeding a test signal into the radar receiver.

b. To avoid difficulties and misleading information, directional couplers have been designed. Directional couplers are superior to other coupling devices in one or more of the following aspects:

(1) The power picked up in a directional coupler is not dependent upon the position of the coupler relative to the standing wave maxima and minima in the r-f line, because a directional coupler does not respond to the reflected wave that produces standing waves, but rather picks up only the wave proceeding from the transmitter. When power is introduced into the radar line by means of a directional coupler, as when testing the receiver, the power goes only in the direction of the receiver.

(2) When using a directional coupler to test a radar, the fraction of power that is picked up is both known and constant from day to day.

(3) In any sort of power measurement, it is most desirable that the r-f impedance presented to the test equipment be good. With a directional coupler, one is provided with a test point that is matched. This is not the case with simple probes inserted into a transmission line.

SECTION 4
MAINTENANCE

1. ECHO-BOX CAVITY.

a. The factors which cause the ringing time of one echo box to differ slightly from that of a similar echo box, unfortunately, are not well understood. Consequently, any operation that might change the mechanical shape of the echo box or damage the silvered surface of the cavity must be avoided, for such factors are probably responsible for the differences mentioned. It is certainly inadvisable to subject the echo box to unnecessarily rough handling. IT IS INADVISABLE TO TAKE THE CAVITY OF THE BOX APART BECAUSE THE RINGING MAY BE CHANGED BY A SMALL PERCENTAGE WHEN THE BOX IS REASSEMBLED. Therefore, the cavity should not be opened except for very good reason.

b. Large changes in ringing will not be caused by *careful* disassembly and reassembly of an echo box of this rugged and precise construction. In the event that it becomes necessary to take the cavity apart (for example, to replace a damaged part), the ringing ability of the reassembled box may be recalibrated by comparing its ringing time on a particular radar with that of another echo box which retains the factory calibration. Then, if necessary, adjusting loop P-104 may now be set to cause the ringing time of the two echo boxes to be the same. Adjusting loop P-103 cannot be satisfactorily set in the field, therefore in taking the box apart it should not be disturbed.

c. MECHANICAL ASSEMBLY AND DIAL SETTING. — Should dismantling of the echo box become necessary, it is important when reassembling that the dial setting have a definite relation to the plunger position. This is necessary in order that the dial calibration retain its relationship to frequency as given in figure 2-2.

To disassemble the echo box, follow the procedure as outlined below:

(1) Remove carrying strap (H-105). Remove the eight ½″ long No. 10-32 fillister-head screws and lockwashers (H-113) and (H-114) respectively and lift off end plate (A-102), rubber gasket (H-133), and rear D-ring (H-106).

(2) Set the dial at a reading of 1200, then measure the distance from the flange of cylinder (A-104) to the finished surface on the back of plunger assembly (O-106). Record this measurement for use in re-assembly.

(3) Remove meter can cover (A-108). This cover is held in place by captive thumb-screw (H-109). Remove index plates (N-105) and (N-106). Remove acorn nut (H-127), lock nut (H-128), and setting indicator (N-103) using socket wrench provided (SA-12651). The complete dial assembly consisting of inner dial (N-102), outer dial (N-101), and associated gears can now be removed as a unit by sliding it off the plunger drivescrew (O-102). Take care that shims (A-116) are not lost when removing the dial. Remove housing (A-105) by removing the six 7/16″ long No. 8-32 fillister-head screws and lockwashers (H-116) and (H-119) respectively and the two ½″ long No. 8-32 fillister-head screws and lockwashers (H-117) and (H-119) respectively which hold the front D-ring holder (H-153). Care should be taken to avoid damage to the gasket (H-132). The plunger drivescrew will remain engaged in the plunger spindle and will slide out of the bearing (O-103) as the housing is removed. If the plunger drivescrew must be removed, unscrew it and handle carefully to avoid damaging its precision ground threads. Remove the plunger assembly (O-106) very carefully to the rear, taking care that the fingers of the plunger and the fingers of the sleeve, attached to front plate (A-103), are not disturbed.

(4) To remove input coupling loop (P-102) and output coupling loop and crystal holder (P-101) use spanner wrench, part No. 4207-ZN, which has been provided for that purpose.

(5) Rectifying crystal (Y-101) may be removed by first removing or loosening connecting wire from binding post (figure 1-3) and then unscrewing the upper portion of the output coupling loop and crystal holder assembly (P-101) and lifting the crystal out of its location in the lower half of the assembly. Spare crystals are contained in spare crystal holder (A-110) and are accessible after unscrewing the knurled cap. In handling crystals, observe the precautions covered in section 4-2.

(6) To reassemble and reset the calibration of the echo box proceed in the following manner:

(*a*) Replace plunger assembly (O-106) again being careful not to disturb the fingers of the plunger and sleeve. Note also that the guide attached to front plate (A-103) must enter into the slot of the tube of the plunger assembly.

(*b*) Screw the plunger drive screw (O-102) about one-half way into the plunger spindle, being careful to avoid crossed threads and grit. Replace paper gasket (H-132) and housing (A-105), properly

locating them by means of the locating pin in the front plate and the locating hole in the housing and gasket. Replace and tighten six 7/16″ long No. 8-32 fillister-head screws. Replace front D-ring holder (H-153) using the two ½″ long No. 8-32 fillister-head screws.

(*c*) Replace shims (A-116), dial assembly, setting indicator (N-103) and lock nut (H-128), but do not tighten lock nut. Set the zero on the inner dial at the mark "120" on the outer dial. Rotate the entire dial assembly until these marks are in alignment with the center of the left index post on housing (A-105), then press gently backward, engaging pinions (O-104) and (O-107) with ring gear (O-105). Replace index plates (N-105) and (N-106). Turn the plunger drivescrew (O-102), moving the plunger assembly (O-106) until the distance from the flange of cylinder (A-104) to the finished surface on the back of plunger assembly (O-106) is just the same as that noted in disassembling. This will be about 23/32″, but will vary slightly from unit to unit. Tighten locknut (H-128) slightly. While still holding dial at 1200, turn plunger drivescrew right or left, whichever is the shortest amount required to cause the pointer of the setting indicator (N-103) to line up exactly with the punch mark on the inside face of inner dial (N-102). Tighten locknut (H-128) and replace and tighten acorn nut (H-127).

(*d*) Replace rubber gasket (H-133) and end plate (A-102) and replace eight No. 10-32 fillister-head screws with back D-ring (H-106) held in place by the two top screws.

(*e*) Replace output and input coupling loops and tighten with spanner wrench (part No. 4207-ZN). Make sure the locating pin lines up with the loop slot.

Reconnect wiring as shown in figure 1-3.

Replace meter can cover (A-108) and carrying strap (H-105).

(*f*) When disassembling and reassembling the echo box care should be exercised to avoid scratching the inside surface of the cavity cylinder and the silver-plated surface of the plunger. Do not distort the fingers.

(*g*) In the event that plunger assembly (O-106) is replaced, electrical readjustment of the echo box is essential. The dial should be set so that the frequency indication agrees with another echo box or with a Model LAE Signal Generator, and loop (P-104) should be adjusted so that the ringing time agrees with another TS-545 echo box. Loop (P-103) should not be changed.

d. LUBRICATION. — The gears within the dial assembly are the only parts of the echo box that need lubrication. A thin coat of lubriplate No. 107 is applied at assembly. No further lubrication is necessary unless gears are replaced.

2. PRECAUTIONS IN HANDLING CRYSTALS

a. Crystal cartridges will stand only a limited amount of mechanical shock and should be handled with the same care as vacuum tubes.

b. In many cases the body of the person handling the crystal unit is not a ground potential, due to his movement across an insulated floor or deck. This is particularly likely to be the case when the humidity is low, as on a dry, cold day, or in heated quarters. The static charge carried by the body might accidentally be discharged through the crystal unit if it is held by the base and the tip is brought into contact with grounded equipment. The same thing might occur if the tip of the unit is at ground potential and its base is touched by a person or object carrying a static charge. Similarly, a static discharge might take place if the crystal is handed from one person to another. In order to avoid damage, certain precautions should always be taken:

(1) Touch the equipment with your bare hand before attempting to insert the crystal.

(2) If you want to hand the unit to another person, touch his bare hand first, in order to equalize any static charge.

c. Crystals also are apt to be damaged by voltages in connecting wires, induced by neighboring electrical equipment. In this way, voltage shocks may be delivered to the crystal by the opening and closing of nearby electrical circuits. Such damage should be avoided by careful shielding of the connecting wires, and by keeping the crystal always wrapped in metal foil or in a metal box when not in use.

d. If a crystal is exposed to a strong radio-frequency field, it may easily absorb enough energy to damage or destroy it. Since it may often be necessary to remove a crystal from its holder or from the spare crystal compartment when in the vicinity of a radar transmitter or other source of high-frequency field, certain precautions must be taken.

The transmitter must be shut down before opening the crystal holder or the spare crystal compartment, otherwise the crystals may be destroyed by strong electromagnetic fields. To replace the crystal, remove the connecting wire and unscrew the top portion of the crystal holder. Remove the old crystal with the fingernails; a pair of pliers should be used only if necessary. Insert the new crystal, observing the precaution set forth above. Note that it makes good contact with the fingers of the center conductor. Replace the top portion of the crystal holder and close the spare crystal compartment before starting the transmitter. Reconnect wire and tighten binding post. If, for one reason or another, it is impossible to shut down the transmitter, the echo box may be removed some distance from the transmitter and the crystal changed.

3. ECHO-BOX METER.

The part of the echo box least resistant to damage by mechanical shock is the meter. This is inevitable with all sensitive meters of present design. Reasonable care in handling is indicated.

If there is reason to suspect that the meter has been damaged, disconnect the meter from the crystal and connect it in series through a 20,000-ohm resistor and a single 1.5-volt dry cell. The meter should read approximately 75. It is not necessary that this reading be obtained exactly.

CAUTION

Never test the echo-box meter with an ohmmeter. The movement is sensitive enough to be damaged by the current from the battery in the ohmmeter.

4. REPLACING CABLE CONNECTORS.

The detailed procedure to be used in replacing connectors is illustrated in figure 4-1. To ensure correct results, follow this procedure exactly, and step by step:

One — Cut back the vinylite jacket square and even as shown.

Two — Push back braid and cut off 1/4 inch of cable dielectric.

Three — Pull braid forward and taper toward center conductor.

Four — Insert cable into clamping nut (1), thin metal washer (2), rubber washer (3), and clamping sleeve (4) in order as indicated. Be sure that clamping sleeve (4) clears all braid wires and its internal shoulder rests squarely against end of vinylite jacket.

Five — Unbraid shield wires, spread open and lay back on clamping sleeve (4) without wires crossing each other. Cut off excess braid wire length so that each wire will end before touching shoulder of clamping sleeve (4). Cut off cable dielectric 5/32″ from end of braid wires. Be sure to cut square and even and do not nich center conductor. Cut center conductor 3/16″ from end of cable dielectric and tin. Solder male contact carefully and remove excess solder. Be careful that solder or flux does not get on end of cable dielectric.

Six — Insert cable into plug as far as it will go. Push rubber washer (3) and thin metal washer (2) into body and tighten clamping nut (1). Hold body with wrench and tighten clamping nut (1). Do not allow body or cable to rotate during this operation.

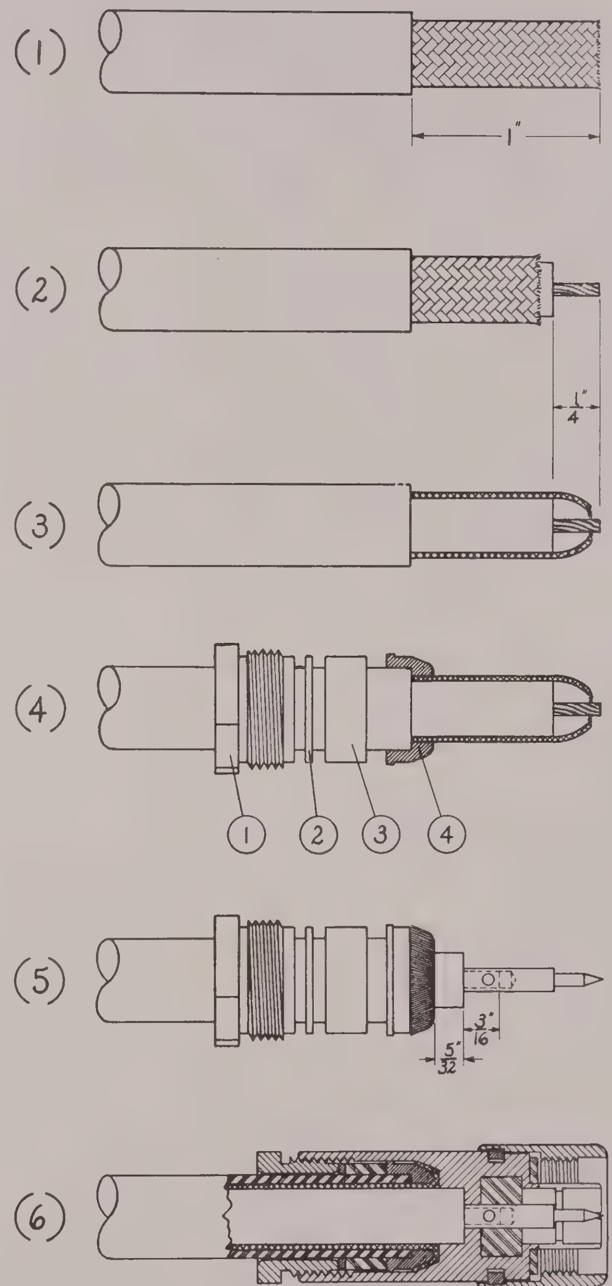


Figure 4-1. Attaching Connectors UG-21B/U to Cables RG-9A/U.

5. TROUBLES WHICH MAY BE ENCOUNTERED WITH ECHO BOX.

a. LOW METER READING. — The meter will read low when:

The radar power is low.

The spectrum of the transmitter is bad.

The pulse is too short.

These are among the system faults which it is the purpose of the echo box to detect. When these conditions do not prevail, the echo-box meter may read low due to the following causes:

(1) The echo box is tuned to a side lobe of the transmitter spectrum. If the transmitter spectrum has large side lobes, it is possible unknowingly to maximize the meter on one of these lobes. This arises only by careless tuning and is readily avoided by first tuning completely through the spectrum and then maximizing the meter by careful adjustment.

(2) Output loop not properly adjusted at installation. See Section 2-1*d*.

(3) Burned out or damaged crystal in the echo box.

(4) Damaged coaxial connectors or faults in the r-f cables. (This is the most probable cause of trouble; consequently, the cable should be handled as little as possible, and, to avoid unnecessary wear on the connectors, in permanent installation it should be left connected when the echo box is not in use.

(5) Directional coupler installed backward. Low meter reading due to this cause and to cause (1) above will always be accompanied by reduced ringing time.

(6) Filter capacitor open or shorted.

(7) Echo-box loop broken. REMOVE METER WIRE and check from binding post to ground for crystal resistance.

(8) Meter damaged. Check as above.

b. LOW RINGING-TIME METER RINGING NORMAL. — Presuming that the radar receiver sensitivity and the T-R box recovery are normal, and the echo-box meter reading is normal, a reduction in ringing time can be caused by echo box damage such as corrosion of the silver plating on the cavity wall over a considerable area, or impaired plunger-finger contact which may change the ringing ability of the echo box. This is not a likely cause of trouble. Compare the echo box with another if possible.

NOTE

While radar performance troubles are usually quickly remedied once it is recognized that trouble exists, there are those cases which may lead an expert to question the test equipment and which, because of their chronic nature, it is particularly important to detect. There is a natural tendency to suspect the test equipment itself whenever a particularly recalcitrant case of radar trouble appears. This test equipment is reliable, and indeed will seldom fail to operate properly if intelligently used. This equipment is fundamentally simple, and ruggedly and reliably made. It is intended to serve as your guide and is worthy of your confidence.

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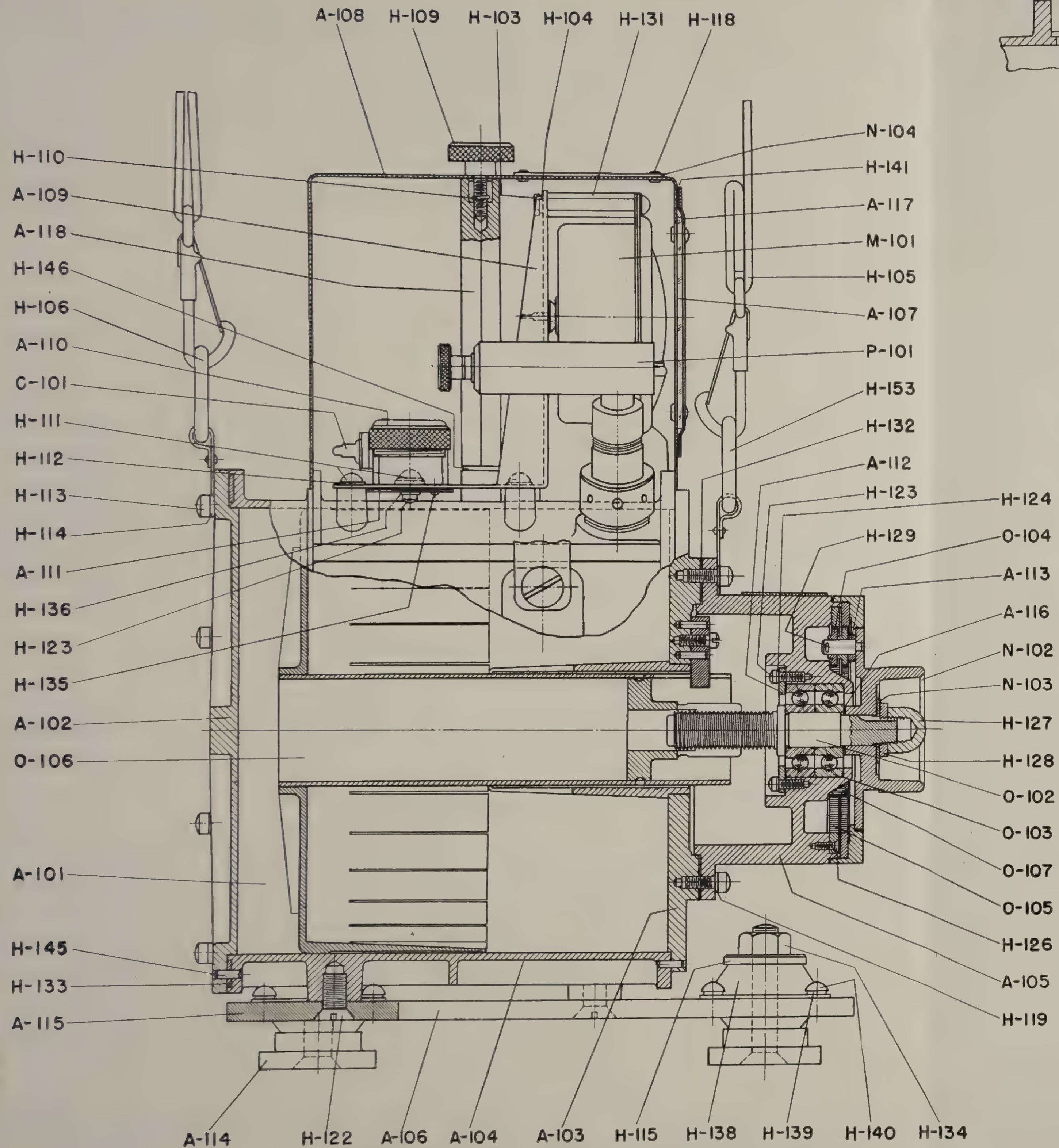
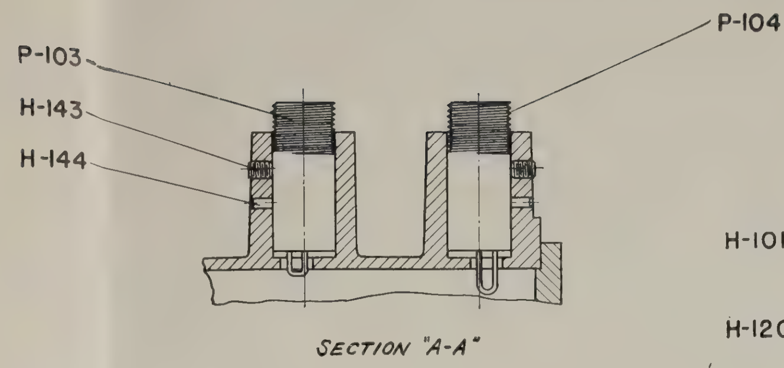


Figure 4-3A — Cross-Section of Echo Box TS-545/UP



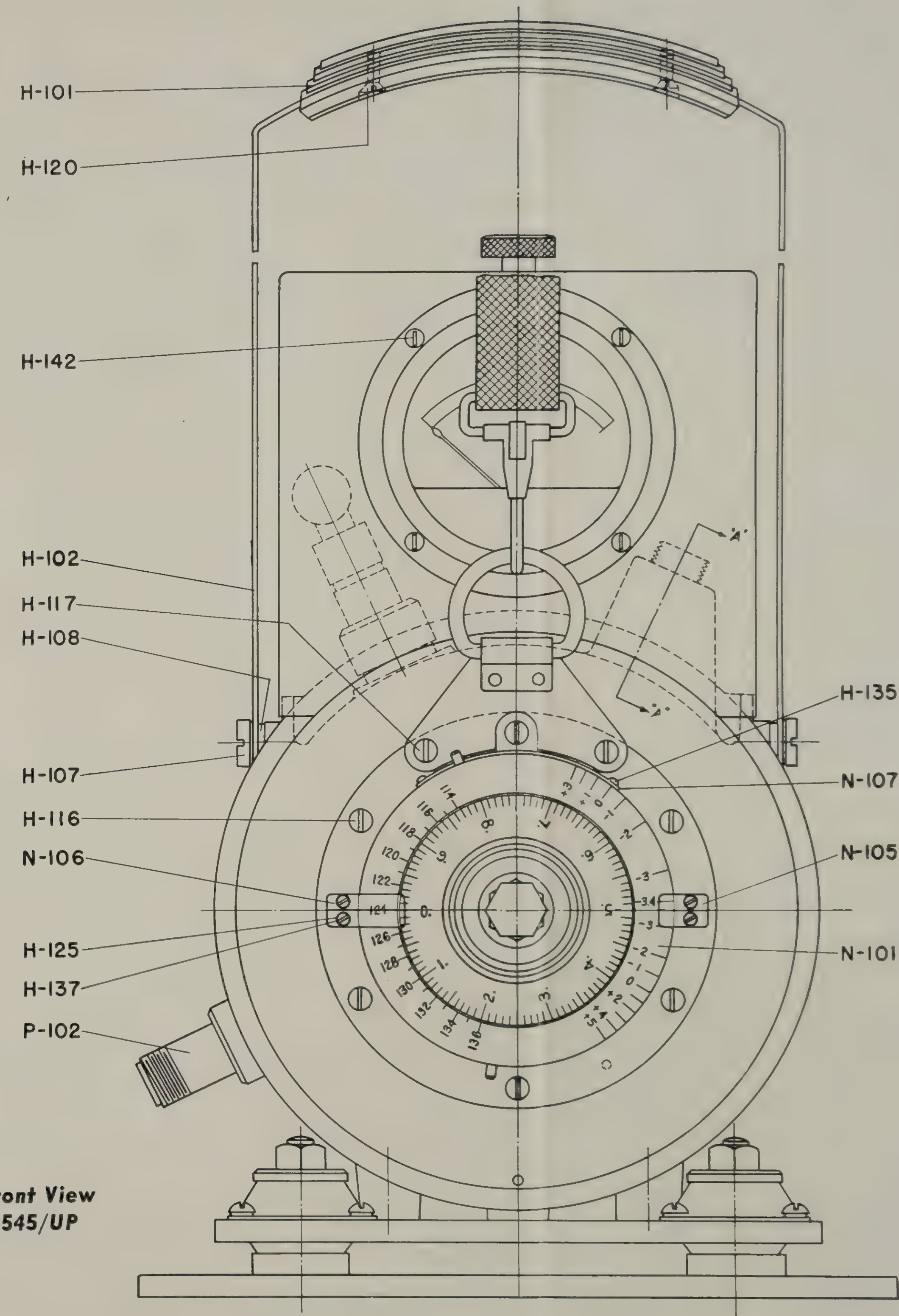


Figure 4-3B—Front View of Echo Box TS-545/UP

Figures 4-3A and 4-3B — Cross Section and Front View of Echo Box TS-545/UP

SECTION 5
PARTS LISTS

TABLE 5-1. WEIGHTS AND DIMENSIONS OF REPAIR PARTS BOXES

Equipment Spares						Stock Spares					
Spare Parts Box	Overall Dimensions			Volume	Weight	Spare Parts Box	Overall Dimensions			Volume	Weight
	Height	Width	Depth				Height	Width	Depth		
1	3⅜″	10½″	11½″	.24 cu. ft.	8 lbs.	1	9″	10″	16″	.84 cu. ft.	23 lbs.

TABLE 5-2. SHIPPING WEIGHTS AND DIMENSIONS OF REPAIR PARTS BOXES

Equipment Spares							Stock Spares						
Shipping Box Number	Spare Parts Box	Overall Dimensions			Volume	Weight	Shipping Box Number	Spare Parts Box	Overall Dimensions			Volume	Weight
		Height	Width	Depth					Height	Width	Depth		
1-137	1	3⅞″	10¾″	12¼″	.3 cu. ft.	10 lbs.	1-12	1	9¼″	10¼″	16¼″	.9 cu. ft.	25 lbs.

TABLE 5-3. LIST OF MAJOR UNITS

Quantity	Name of Major Unit	JAN or Navy-Type Designation	Symbol Group
1	Echo Box Test Set	TS-545/UP F16-W-47074-5535	101 to 199

TABLE 5-4 COMBINED PARTS & REPAIR PARTS LIST

Symbol Desig.	Name of Part and Description	Function	JAN. and (Navy Type) Number	Standard Navy & (Signal Corps) Stock No.	Mfr. and Mfr's. Designation	Contractor's Part Number	Contractor's Drg. No.	Total No. Per Equip.	SPARE PARTS Equip.	SPARE PARTS Stock
	STRUCTURAL PARTS									
A-102	End Plate; brass cstg; 7″ dia. silver plated on interior surface, zinc chromate and enameled on exterior surfaces.	Covers rear end of cyl.			10 27906	27906	17487	1		
A-103	Front Plate assembly; brass cstg. $6\frac{1}{2}$″ dia.; zinc plated, zinc chromate and enameled.	Covers front end of cyl.			10 27907-SA	27907-SA	17489	1		
A-104	Cylinder assembly; brass cstg; 6″ bore, $5\frac{13}{16}$″ long, silver plated on interior surface, zinc chromate and enameled on exterior surfaces.	Resonant Cavity			10 27893-SA	27893-SA	38706	1		
A-105	Housing Assembly; zinc plated all over, irridite dip and enameled on exterior surfaces.	To mount dial assembly and bearing			10 27908-SA	27908-SA	17603	1		
A-106	Plate Mounting; aluminum; $\frac{1}{4}$″x$7\frac{1}{8}$″x$8\frac{3}{8}$″, anodized and enameled all over.	To mount echo box			10 27936	27936	17496	1		
A-107	Window, lumarith; $2\frac{7}{8}$″ dia. x .060″ thk.	To view meter		N17-W-56092-6603	10 24998	24998	30503	1		
A-108	Box Assembly; #20 B.&S. sheet brass; zinc chromate and enameled all over.	To house meter			10 27932-SA	27932-SA	38708	1		
A-109	Bracket Assembly; #16 B.&S. sheet brass; zinc plated all over. Also includes spare crystal holder.	To mount meter			10 27917-SA	27917-SA	17499	1		
*A-110	Nut, Cap; brass; zinc plated; $1\frac{1}{16}$″ dia. x $\frac{5}{16}$″ high; $\frac{15}{16}$″—18 female thread; $\frac{7}{32}$″ deep.	Cap for crystal holder		(2Z1619-14) N43-N-2504-800	10 24808	24808	30334	1		
A-111	Spring, Flat; #30 B.&S. phos. bronze sheet, spring temper; zinc plated.	To load spare crystals		N17-C-812002-741	10 24924	24924	30449	1		
A-112	Ring, Bearing Retaining; brass; $1\frac{11}{16}$″ O.D. x $\frac{15}{16}$″ I.D. x .101″ thick.	To hold 0-103 in place		N16-R-500371-128	10 24789	24789	30321	1		
A-113	Spacer, Pinion; brass; $\frac{11}{32}$″ O.D. x .189″ I.D. x .087″ thick; zinc plated.	To line up pinions with gear		N16-W-180001-174	10 24832	24832	30342	3		
A-114	Mounting Strip Assembly, steel; zinc plated.	Attaches to mounting plate			10 27951-SA	27951-SA	32730	2		
*A-115	Spacer, brass; $1\frac{1}{8}$″ O.D. x $\frac{25}{64}$″ I.D. x $\frac{1}{4}$″ thick, zinc plated.	Separates mgt. strip from shock mount		N43-W-3173-345	10 24984	24984	30505	4		

A-116	Shim; brass; $21/32''$ O.D. x .390″ I.D. x .003″ thk. zinc plated.	To take up end play		(2Z8320-16) N43-W-3173-297	10 24810	24810	30336	5	
A-117	Bezel, #20 B.&S. sheet brass; zinc chromate and enameled on exterior surfaces.	Holds window in place		N16-B-300001-121	10 24999	24999	30504	1	
*A-118	Stud; $1/2''$ hex. steel, zinc plated; $4\,3/32''$ lg; $3/8''$-24 male thrd. $11/32''$ lg. one end; #10-32 female thrd. $5/8''$ deep other end.	To fasten A-108 to A-101			10 27934	27934	32709	1	
	CAPACITORS								
C-101	Capacitor, fixed: paper dielectric 1 mfd+20%−10%; 40 vdcw; hermetically sealed metal case; $1\,13/16''$ long x 1″ wide x $7/8''$ high; wax filled and impregnated; two rivet lug term, located on top; two mtg feet W/$3/16''$ dia. hole in each on $2\,1/8''$ centers.	Filter	CP53B1 EB105V	N16-C-48841-9420	9 9195BW	SPC-8783		1	1
	MECHANICAL PARTS								
H-101	Handle; moulded bakelite; 5″ lg x $1\,1/16''$ wide x 1″ high overall; 2 pc. black.	To carry echo box		N16-H-150001-162	10 SPC-11777	SPC-11777	33120	1	1
H-102	Handle Arm, #14 B.&S. sheet brass; zinc plated.	To carry echo box			10 28553	28553	17601	1	
H-103	Nut, brass, cad. plated; $1/4''$ hex, #6-32, Thr'd, .081″ thk.	To secure H-131			10 756-CA	756-CA		3	
H-104	Lockwasher, #6 Split, bronze, cad. plated.	To lock H-103			Commercial	22521-CA	15186	3	
*H-106	Dee Ring Holder Assembly; rear; brass, zinc plated.	To snap on carrying strap			10 28059-SA	28059-SA	33097	1	
H-107	Screw, Handle Arm Shoulder; brass, zinc plated; $1/4''$—28 thread.	To fasten H-102 to A-104		(6L7928-4-5-1.5A)	10 24819	24918	30340	2	
H-108	Lockwasher, $1/4''$ Split; bronze, zinc plated.	To lock H-102			Commercial	SPC-3343-ZN		2	
H-109	Screw, Shoulder; brass; #10-32 thread; zinc plated.	Holds A-108 in position			10 25867	25867	31198	1	
H-110	Washer, Spring; #22 B.&S. bronze wire; zinc plated.	To keep H-109 in place		(2Z8877.77)	10 24953	24953	30465	1	
H-111	Screw, $1/4''$ #8—32 Round Hd. Brass Mach.; zinc plated.	To fasten A-109 and C-101			Commercial	SPC-1392-ZN		6	
H-112	Lockwasher, #8 Shakeproof; zinc plated.	To lock H-111			14 Type 19	SPC-8474-ZN		6	
H-113	Screw, $1/2''$ #10—32 Fill. Hd. Brass Mach.; zinc plated.	To secure A-102 to A-104			Commercial	SPC-8491-ZN		8	
H-114	Lockwasher, #10 Split; steel, zinc plated.	To lock H-113			Commercial	22713-ZN	11309	8	

* For contract NObsr-52092, material is aluminum, anodized.

Repair parts listed (quantities) were furnished under contract NObsr-39392.

TABLE 5-4 COMBINED PARTS & REPAIR PARTS LIST (CONT.)

Symbol Desig.	Name of Part and Description	Function	JAN. and (Navy Type) Number	Standard Navy & (Signal Corps) Stock No.	Mfr. and Mfr's. Designation	Contractor's Part Number	Contractor's Drg. No.	Total No. Per Equip.	Spare Parts: Equip.	Spare Parts: Stock
	MECHANICAL PARTS (CONT.)									
H-115	Washer; steel, zinc plated; 1⅛" o.d. x 11/32" i.d. x ⅛" thk.	To load H-138			10 28673	28673	33132	4		
H-116	Screw, 7/16" #8-32 Fill. Hd. Brass Mach.; cad. plated.	To secure A-105 to A-103			Commercial	SPC-5403-CA		6		
H-117	Screw, ½" #8—32 Fill. Hd. Brass Mach.; cad. plated.	To fasten H-153 to A-103			Commercial	SPC-8389-CA		3		
H-118	Rivet, hollow brass; .063" dia. x 3/32" long, zinc plated.	To secure N-104 to A-108			Commercial	SPC-9077-ZN		4		
H-119	Lockwasher, #8 Split; bronze; zinc plated.	To lock H-116 and H-117			Commercial	SPC-9758-ZN		9		
H-120	Screw, ⅜" #6—32 Flat Hd. Brass Mach.; cad. plated.	To secure H-101 to H-102			Commercial	SPC-1453-CA		2		
H-122	Screw, ¾" 5/16"-18 Flat Hd. Iron Mach.; cad. plated.	To secure echo box to A-106			Commercial	SPC-2023-CA		3		
H-123	Screw, ¼" #4—40 Fill. Hd. Brass Mach.; zinc plated.	To hold O-103 and A-111 in position			Commercial	SPC-8279-ZN		5		
H-124	Lockwasher, #4 Split; bronze; zinc plated.	To lock H-123 holding A-112			Commercial	22712-ZN	11309	4		
H-125	Lockwasher, #2 Split; bronze; zinc plated.	To lock H-137			Commercial	22714-ZN	11309	4		
H-126	Screw, 3/16" #2—56 Fill. Hd. Brass Mach.; zinc plated.	To secure O-105 to A-105			Commercial	SPC-828-ZN		3		
H-127	Nut, Acorn; adj. post; brass, ⅜"—24 thread; ½" high, zinc plated.	To lock H-128		(6L3746-24.2A)	10 24874	24874	30402	1		
H-128	Nut, adj. post; brass, ⅝" hex, ⅜"—24 thread; 7/64" thick; zinc plated.	To secure N-102 to O-102		(6L3746-24.10)	10 24873	24873	30401	1		
H-129	Pin, Cotter; brass; 3/64" dia. x ⅜" long; zinc plated.	To hold O-104 in place			Commercial	SPC-8627-ZN		3		
H-130	Pin, #18 Brass Esc.; ¼" Lg.; zinc plated.	To hold N-105 in place			Commercial	SPC-264-ZN		2		
H-131	Spacer, meter; brass, zinc plated; 5/16" hex, 1 13/32" lg; #6-32 male thrd. ¼" lg one end; #6-32 female thrd., 3/16" deep other end.	To support M-101			10 28063	28063	35186	3		

H-132	Gasket, front plate; Kraft paper; $4\frac{5}{8}''$ O.D. x $3\frac{13}{32}''$ I.D. x .010″ thick; 9 holes.	Seal for A-103		N17-G-162930-825	6	28060	32728	1	1
H-133	Gasket, cylinder; synthetic rubber; $6\frac{13}{16}''$ O.D. x $6\frac{3}{16}''$ I.D. x $\frac{1}{16}''$ thick; 12 holes.	Seal for A-104		N17-G-163846-663	7 GLR-214	28062	17498	1	1
H-134	Nut; steel, zinc plated $\frac{5}{16}''$—18 thread.	Fasten A-101 to A-114			Commercial	SPC-3536-ZN		4	
H-135	Pin, #18 Brass Esc.; $\frac{1}{8}''$ long; zinc plated.	To locate A-111			Commercial	SPC-8667-ZN		3	
H-136	Lockwasher, #4 Shakeproof; bronze, zinc plated.	To lock H-123			14 Type 19	SPC-9500-ZN		1	
H-137	Screw, $\frac{3}{16}''$ #2—56 Fill. Hd. Brass Mach.; zinc plated.	Holds N-105 and N-106			Commercial	SPC-828-ZN		4	
H-138	Mount, vibration: syn. rubber cush. $1\frac{1}{2}''$ dia. x $\frac{15}{16}''$ h; bolt hole in cush. $\frac{23}{64}''$ dia.; st'less st. mtg. plate $1\frac{3}{4}''$ sq. with 4 mtg. holes .166″ dia. on $1\frac{3}{8}''$ centers; 10 lb. load rating.	Shock mounting		(2Z8403-31) N17-M-75034-3451	3 LW-5210 less bushing and Washers	SPC-8773		4	
H-139	Lockwasher, #8 Split bronze, zinc plated.	To lock H-140			Commercial	SPC-9758-ZN		16	
H-140	Screw, $\frac{3}{8}''$ #8—32 Round Hd. Brass Mach.; zinc plated.	To hold H-138 in place			Commercial	SPC-848-ZN		16	
H-141	Gasket, Bezel; Kraft paper $3\frac{5}{8}''$ O.D. x $2\frac{3}{4}''$ I.D. x .010″ thick; 4 holes.	Seal for bezel		(2Z4866.133) N17-G-162458-746	6	24792	30324	1	1
H-142	Screw, $\frac{1}{8}''$ #4—40 Round Hd. Brass Mach.; zinc plated.	To secure A-117 to A-108			Commercial	SPC-8738-ZN		4	
H-143	Screw, set; $\frac{3}{16}''$ #8—32 Allen Hd., Cup Point; zinc plated.	To lock P-103 and P-104			Commercial	SPC-11192		4	
H-144	Pin, loop; brass; .092″ dia. x $\frac{1}{4}''$ long.	To guide P-103 and P-104			10 28064	28064	35187	2	
H-145	Pin; brass, zinc plated; 0.110″ dia. x 0.343″ long.	To locate A-102			10 24784	24784	30316	2	
H-146	Lockwasher; $\frac{1}{4}''$; bronze, cad. plated	To lock A-118			14 Type 19	SPC-8661-CA		1	
H-150	Washer, loop gasket; syn. rub.; .785″ O.D. x .625″ I.D. x $\frac{1}{16}''$ thick. Used on Input loop.	Seal for Input loop		(2Z4867.168) N33-W-312-7890	12 C-3679-K	24890	30415	1	1
*H-153	Dee Ring Holder Ass'bly; Front; Brass, Zinc Plated	To snap on carrying strap			10 25866-SA	25866-SA	33096	1	
	METER								
M-101	Microammeter; DC; 0 to 100 microamp; hermetically sealed. $2\frac{11}{16}''$ dia. back; 3-equally spaced mtg. holes on $3\frac{1}{8}''$ dia. bolt circle; $3\frac{1}{2}''$ dia. flange	Tuning Indicator	MR36W100 DCUA	N17-M-18968-6601	11 Model HM3	SPC-11006		1	
	NAME PLATES AND DIALS								
N-101	Dial Assembly, Outer; with dial gear pressed in place, etched and zinc plated.	Tuning assembly			10 24961-SA	24961-SA	17500	1	
N-102	Dial Assembly, Inner; with pinion shafts brazed in place, etched and zinc plated.	Tuning assembly			10 SA-16010	SA-16010	33049	1	

* For contract NObsr-52092, material is aluminum, anodized.

Repair parts listed (quantities) were furnished under contract NObsr-39392.

TABLE 5-4 COMBINED PARTS & REPAIR PARTS LIST (CONT.)

Symbol Desig.	Name of Part and Description	Function	JAN. and (Navy Type) Number	Standard Navy & (Signal Corps) Stock No.	Mfr. and Mfr's. Designation	Contractor's Part Number	Contractor's Drg. No.	Total No. Per Equip.	SPARE PARTS Equip.	SPARE PARTS Stock
	NAME PLATES AND DIALS (Cont.)									
N-103	Washer, Dial, #20 B.&S. Phos. Bronze, zinc plated.	Setting Indicator		(6L50156N)	10 24875	24875	30403	1		
N-104	Name Plate for Contract N0bsr-39392.	Identification			5	28065	32731	1		
N-104	Name Plate for Contract N0bsr-42382.	Identification			5	28733	32731	1		
N-104	Name Plate for Contract N0bsr-49089.	Identification			5	29623	33563	1		
N-104	Name Plate for Contract N0bsr-52092	Identification			5	30508	33563	1		
N-105	Indicator, Dial; .060″ thk. Transparent lumarith.	To indicate dial reading			10 28562	28562	32967	1		
N-106	Indicator, Dial, .060″ thk. transparent lumarith.	To indicate dial reading			10 28561	28561	32967	1		
N-107	Plate, Instruction.	To furnish inst.			5	28531	32946	1		
	MECHANICAL PARTS									
O-102	Screw, Plunger Drive; type 420-F Stainless steel Hardened and drawn to Rockwell C 48-52; ½″—25 thread.	To operate plunger			10 27940	27940	32713	1		
O-103	Bearing, Ball: preloaded; single row angular, plain; light duty; 0.4724″ bore, 1.2598″ O.D., 0.3937″ wide; 8 balls; tight fit; ABEC-5 tol.	To locate O-102		G77-B-134-01202-6360	15 7201CTC-C78/G1	SPC-11678		2		
O-104	Pinion, brass; 33 teeth (external) 64 pitch .516″ pitch dia., .547″ O.D.	Support of outer dial		(2Z4875-41) N16-G-431550-264	10 24958	24958	30479	4		
O-105	Gear, Stationary; brass; 177 teeth (internal) 64 pitch, 2.766 pitch dia., 3.379″ O.D.	To rotate pinions		(2Z4875-41) N16-G-422050-562	10 24954	24954	30475	1		
O-106	Plunger Assembly, brass; silver plated.	Plunger			10 27914	27914	17497	1		
O-107	Pinion, Combination; brass; 33 teeth (external) 64 pitch, .516″ P.D.; .547″ O.D.	To transmit rotation from inner to outer dial			10 24959	24959	30480	1		
O-110	Dial assembly; vernier; br. zinc pl.; 3⅝″ dia. x 1⅜″ d. overall; accommodates ⅜″ dia. shaft; assembly consists of the following Johnson Service Co. parts: 4—#24958 Pinion, 1—#24959 Combination Pinion, 3—#24832 Pinion Spacer, 3—#24957 Pinion Shaft, 1—#25145 Inner Dial, 1—#24955 Dial Gear, 2-24784 Pin, 1—#24961 Outer Dial; Inner Dial has 10 major div. 0 to 10 c't'r-clockwise and 100 minor div. in 360°; Outer Dial has 22 div. on 1.275″ rad. in 132° arc, 16 div. on outer dia. of dial in 124°-12′ arc.	Tuning assembly		N16-D-46570-1001	10 SA-16018	SA-16018	17687	1		

	PLUGS, JACKS AND COUPLERS								
P-101	Probe, RF: angular, adjustable; output ckt. of echo box output loop; brass, silver plated; $2\frac{15}{16}''$ x $2\frac{7}{8}''$ x $1''$ dia.; $\frac{1}{4}$ turn of 0.052″ dia. brass wire on 0.036″ rad.	Coupler		N16-P-87011-7802	10 SA-15966	SA-15966	17586	1	1
P-102	Probe, RF: input ckt. of echo box input loop; brass, silver plated; built in resistor (51 ohms); 2″ lg. x 1″ dia.; $\frac{1}{4}$ turn of 0.046″ lead wire on 0.039″ rad.	Input to echo box		N16-P-87011-7783	10 SA-15964	SA-15964	17583	1	1
P-103	Trimming Loop, front; br., sil. pl.; built in resistor (200 ohms); $1\frac{13}{16}''$ long x $\frac{5}{8}''$ dia.; $\frac{1}{4}$ turn of 0.046″ lead wire on 0.055″ rad.	Resistive loading device			10 SA-15969	SA-15969	32725	1	
P-104	Trimming Loop, rear; br., sil. pl.; built in resistor (200 ohms); $1\frac{11}{16}''$ long x $\frac{5}{8}''$ dia.; $\frac{1}{4}$ turn of 0.046″ lead wire on 0.055″ rad.	Resistive loading device			10 SA-15970	SA-15970	32880	1	
P-110	Connector, plug: male contact, brass, silver plated. Used with cable RG-9A/U.	Connector	UG-21B/U	N17-C-71416-2550	2	SPC-11775		1	2
	WIRE CABLES, ETC.								
W-101	Cable assembly, RF; uses AN cable RG-9A/U; 9′-10″ lg excluding terminations; 10′ lg ±3″ overall; AN connector, Male contact UG-21B/U on each end.	RF input connector	CG-92B/U (10′)	N16-C-11616-5590	2	SPC-11776		1	
W-101	*Cable Assembly, RF; Uses AN Cable RG-9A/U; 11′-10″ lg. excluding terminations; 12′ lg. ± 3″ overall; AN Connector, Male Contact UG-21B/U on one end.	RF Input Connector	CG-92B/U (12′)	N16-C-11616-6801	2	SPC-12626		1	
	CRYSTALS								
Y-101	Crystal Unit, rectifying: detector type; porcelain body with brass fittings; $\frac{27}{32}''$ lg x $\frac{19}{64}''$ max. dia.	Rectifier	1N21B	(2JIN21B) N16-T-51721-10	16	SPC-8651		4	
	ACCESSORIES								
	Wrench, Socket; st., zinc pl.; $\frac{5}{8}''$ hex; Body $2\frac{1}{2}''$ lg x $\frac{7}{8}''$ dia.; T-handle 3″ lg x $\frac{1}{4}''$ dia.			(6R57420.2) N41-W-2647-60	10 SA-12651	SA-12651	30495	1	1
	Wrench, spanner; size 1″; forged st., zinc pl.; 4″ lg overall x $\frac{13}{16}''$ w. x $\frac{3}{16}''$ thk.; $\frac{1}{8}''$ dia. pin.			(6R57528) N41-W-3255-95	10 4207-ZN	4207-ZN	30417	1	1
	Strap, carrying; 1″ wide cotton webbing, tropicalized; 4 ft. 6″ lg. max; adj.; steel snap on each end. All hardware zinc pl.			(2Z9052-70) N16-S-690501-110	1	SPC-8680		1	

Repair parts listed (quantities) were furnished under contract NObsr-39392.
* Furnished on Contracts NObsr-43457, NObsr-49254 and NObsr-52404.

TABLE 5-5
LIST OF MANUFACTURERS

Code	Mfr's Prefix	Manufacturer	Address
1		Abel & Bach Co.	Milwaukee, Wisconsin
2	CPH	American Phenolic Corp.	Chicago, Ill.
3	CAYU	Barry, L. N. Co.	Cambridge, Mass.
4		Biersach & Niedermeyer	Milwaukee, Wisconsin
5	CAHW	Crowe Name Plate & Mfg. Co.	Chicago, Illinois
6		Detroit Gasket & Mfg. Co.	Detroit, Michigan
7		Great Lakes Rubber Co.	Milwaukee, Wisconsin
8		Industrial Products Co.	Danbury, Conn.
9	CIE	Industrial Condenser Corp.	Chicago, Illinois
10	CABV	Johnson Service Co.	Milwaukee, Wisconsin
11		Marion Elect. Instr. Co.	Manchester, N. H.
12		Marathon Co.	Attleboro, Mass.
13		Precision Products Co.	Milwaukee, Wisconsin
14	CAXO	Shakeproof Incorporated	Chicago, Illinois
15		S. K. F., Inc.	Philadelphia, Penn.
16	CHS	Sylvania Electric Prod., Inc.	Chicago, Illinois

TABLE 5-6 SUPPORT FOR ECHO BOX TS-545/UP

CONTRACT NObsr-52092

Ref. Symbol	Noun	Contractors P/N	Contractors Drw. No.	AF Stock No.	Qty. Equip. Spares	Total Qty. Stock Spares	Unit Pack
A-110	Nut Cap	24808	30334	3300-286688650	0	30	5
C-101	Capacitor	SPC-8783		3300-316958807	0	40	1
H-101	Grip Handle	SA-16421	18103	7800-398100	0	0	1
H-133	Gasket	28062	17498	7800-359197	0	0	1
H-138	Mount	SPC-8773		3300-295594895	0	0	
H-141	Gasket	24792	30324	3300-291609974	0	0	
H-150	Gasket	24890	30415	3300-291612342	2	100	10
M-101	Meter	SPC-11006		3300-328625024	0	50	1
O-103	Bearing Ball	SPC-11678		3400-302452	0	100	1
O-110	Dial Assy	SA-16018	18104	7800-895100	0	40	1
H-127	Nut Acorn	24874	30402	1690-651934220	0	22	1
H-128	Nut Adj	24873	30401	6700-350755-3	0	22	1
O-102	Screw	27940	32713	7800-711343	0	10	1
O-106	Plunger	27914-SA	17497	7800-647050	0	10	1
P-101	Probe — (Broken down)						
	Nut-clamping	28879	33142	7800-595039-5	0	22	1
	Sleeve	25914	31239	7800-725615	0	22	1
	Loop Assy	SA-16419	34002	7800-657100-5	0	22	1
	Tube Assy	SA-16420	18106	7800-185999	0	22	1
P-102	Probe — (Broken down)						
	Nut-Clamping	26848	31842	7800-595039	0	22	1
	Loop Tube	SA-16422	18107	7800-657100	0	22	1
	Cable RG-9 A/U (Part of W-101)	SPC-12627			0	300	150 ft
P-103	Loop Trimmer	SA-15969	32725	7800-472820	0	10	1
P-104	Loop Trimmer	SA-15970	32880	7800-472820-5	0	10	1
P-110	Connector	SPC-11775		8800-467462	0	80	1
Y-101	Crystal Unit	SPC-8651		3300-234137020	8	0	1
	Wrench-Socket	SA-12651	30495	3300-630712410	0	24	1
	Wrench-Spanner	4207-ZN	30417	7900-686570	0	0	
	Strap	SPC-8680	18436	3300-296538268	0	24	1

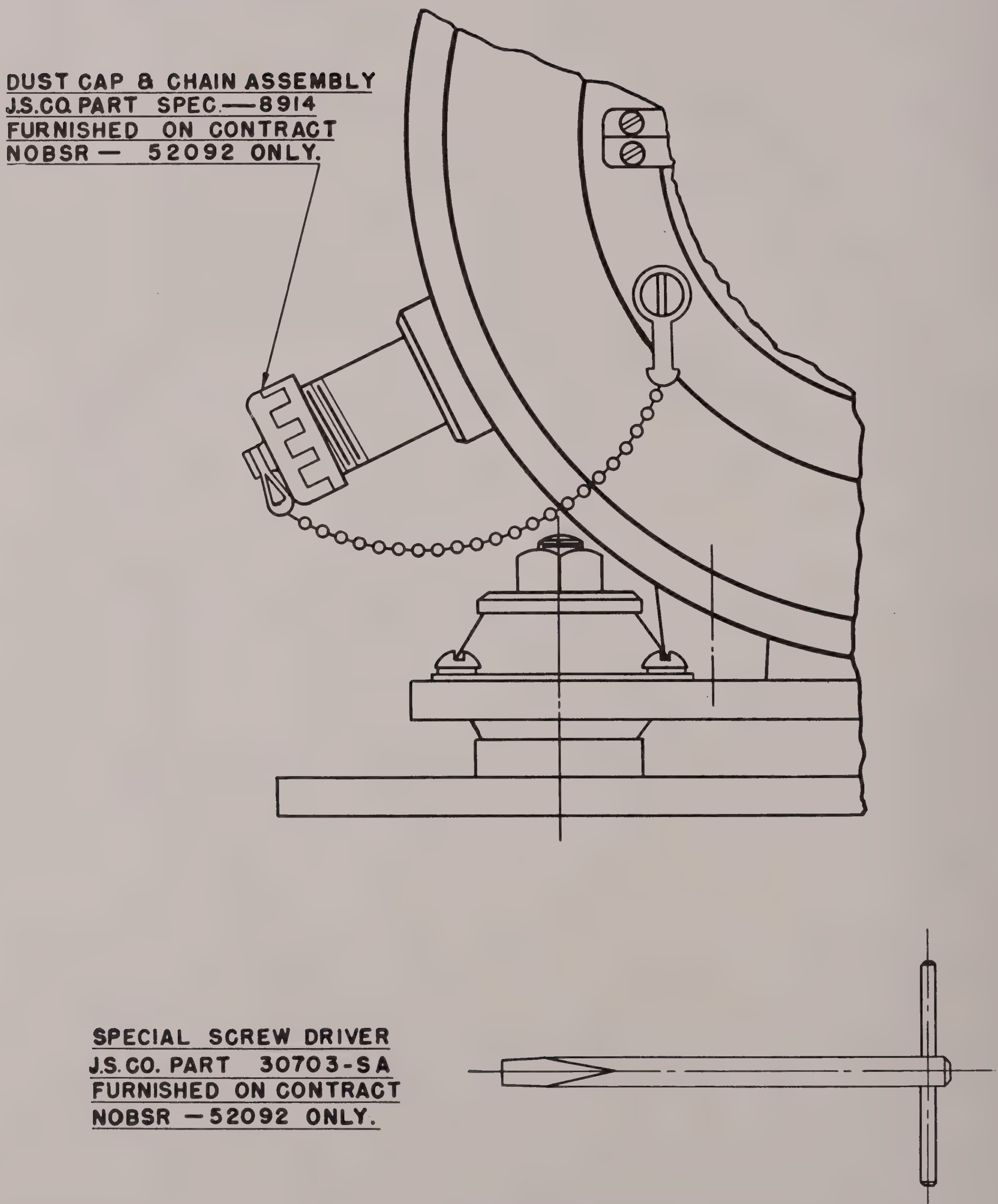


Figure 5-1. Special Equipment Furnished on Contract NObsr-52092 Only.

SECTION 6

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